

# POPULAR SCIENCE

FEATURING:

## A THREE- WHEELED SUPERCAR



Virtual Reality  
Death by Black Hole  
Hydrogen Fuel Cell  
Selfie Drone  
Google's Project Loon  
Cyborg Roach  
Large Hadron Collider  
And...a Baseball

APRIL 2015

### INSIDE THE DARK WEB

A CAUTIONARY TOUR PG. 20

### REVERSING DISEASE

How science is fighting  
five notorious illnesses

### CAN YOU BE ALLERGIC TO TECHNOLOGY?

We visit a small town in  
West Virginia to find out

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**Volume 286 No.4**



## Reversing Disease

Novel treatments are poised to turn back the clock on five devastating illnesses, including Alzheimer's and blindness.

**CASSANDRA WILLYARD**

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## Featuring

### How It Works

Curious about the world? Us too. In our 10th annual celebration of geeky insights, we dissect everything from the Large Hadron Collider to a virtual reality headset and a hydrogen car.

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### Counter Piracy

Brute force hasn't eliminated pirate attacks. But clever new technology from a handful of start-ups very well could.

**ERIK SOFGE**

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### Greetings From the Quiet Zone

Green Bank, West Virginia, doesn't have cell service, Wi-Fi, or radio frequencies—and that's why people are moving there.

**STEVE FEATHERSTONE**

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Illustration by **Panicdtw.com**



## From the Editor

# The Power of Understanding

**L**ike many people, I have been watching the recent measles outbreak with mounting dismay. As of press time, there were more than 120 reported cases and climbing. This, for a disease the Centers for Disease Control and Prevention (CDC) declared eradicated in the U.S. 15 years ago. That more

people are at risk today than a decade ago is sad. We should be moving forward, not backward. But how we get here is perhaps even sadder.

As someone who makes a living communicating science, I can't help but notice an extraordinary disconnect on the issue of vaccines. On one side, there are those who believe a discredited and de-licensed doctor, Andrew Wakefield, as well as various celebrity anti-vaxxers. Politicians who can't seem to decide where they stand only make things worse.

On the other side, there's science. Study after study has shown vaccines to be safe. The CDC estimates they will save 732,000 lives and prevent 21 million hospital visits among children born in the past 20 years. Also, there is no documented connection between vaccines and the anti-vaxxers' central concern, autism. Even Autism Speaks, the world's largest autism science and advocacy organization, comes down strongly in favor of immunization.

So why the dissonance? At the

risk of sounding clichéd, I think that often we fear what we don't understand. Gain a little insight and fear slips away. Plus, understanding things is fun. I mean, how else will you lord your towering intellect over your friends?

It's with this spirit that we undertake our 10th annual How It Works issue. In it, we rip apart some of the world's coolest and most important stuff to see what makes it tick. This year, we dig into a cutting-edge cancer treatment, virtual reality, black holes, a drone that follows its pilot, and much more. One item we consciously left off the list: vaccines. That's because there's so much credible information out there already, if you're curious enough to look.

In line with explaining how things work, I'd also like to shed some light into our operation. This month, we're switching our iPad edition platform. *Popular Science*

WE RIP APART SOME OF THE WORLD'S COOLEST AND MOST IMPORTANT STUFF TO SEE WHAT MAKES IT TICK."



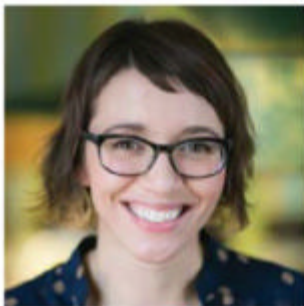
*Plus* is free to print subscribers, so if you own an iPad and haven't yet signed up for it, well, you should—because it's awesome. Download the app, go to "My Account," fill in the credentials, and you're all set.

If you're already a *Popular Science Plus* reader, the change going forward won't mean a whole lot—other than faster download times, which are always nice. All you need to do is update the app. The How It Works issue will be there waiting for you.

Enjoy the magazine.

**Cliff Ransom**  
Editor in Chief

## Contributors



### Cassandra Willyard

Whether reporting on New York's dirtiest stretch of water or on circumcision to prevent HIV in Uganda, writer Cassandra Willyard has an eye for science and public impact. While researching "Yes, You Can Reverse Disease" (page 50), she was amazed by the pace of recent medical progress. "Often in medicine, you see incremental advances," she says, "but these are big, bold efforts."



### Steve Featherstone

Like most of us, writer Steve Featherstone is gadget-dependent. So when he visited a region in West Virginia where electromagnetic waves from cellphones and Wi-Fi are forbidden, it was disorienting. "I couldn't text, email, or call to set up meetings," he says. His story, "Greetings From the Quiet Zone" (page 54), follows electrosensitives—people who claim such waves harm them.



### Heather Hansman

The idea of public data banks for our DNA is an ethical minefield to many of us. But when writer Heather Hansman looked into it, she says, "I was surprised by how unworried the people who worked directly in the field were about privacy." Her report, "Should You Trust Big Pharma with Your DNA?" (page 32), ended up piquing her curiosity. She now wants to examine her own genetic makeup.



### Will Styer

When he's not playing chess or biking in Brooklyn, photographer Will Styer lives behind his lens. To shoot the objects in this month's Now section, including an 88-inch Samsung TV (page 18), he looks for "little moments of shapes, colors, textures, and shadows." TVs are a challenge because they are designed to be unobtrusive. It's also tough to lug a 6-foot-tall box up the studio's stairs.



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# ARCHITECTURE, QUANTIFIED

When completed later this year, Shanghai Tower [page 22] will be the second tallest building in China. It also represents a new design-intensive approach to architecture that stands in contrast to older methods.

**40**

Number of architectural drawings used to design Chicago's Sears Tower (now known as the Willis Tower)

**5,000**

Number of drawings used to design the Shanghai Tower



# AN EARLY LOOK AT VIRTUAL REALITY



In June 1993, *Popular Science* tested virtual reality headsets. The technology was much less mature than it is today [page 37], but the experience was no less eye-opening:

"As I put on a belt pack, an attendant tightens the visor over my glasses like a blindfold. I'm given about a minute to orient myself in a cartoonlike world. The resolution is noticeably lower than the pictures on the monitors. Pushing a button on

the joystick moves me forward in the picture. I can also turn around 180 degrees, look up over my shoulder, or squat down, and the view adjusts accordingly. 'Insert credits,' booms a disembodied voice from within the helmet. The game begins."

# MISSION REPORT

In early March, NASA's Dawn spacecraft began to orbit the dwarf planet Ceres—the largest unexplored object that lies between the sun and Pluto. Dawn's data could help explain the birth of our solar system. Needless to say, we're excited, and we're covering the mission's every step, including the findings, detailed imagery, and the ion thrusters that made the awe-inspiring journey possible, at [popsci.com/ceres](http://popsci.com/ceres).

# WHAT WE'D MISS IF WE LIVED IN THE NATIONAL RADIO QUIET ZONE

"Spark plugs. I used to observe at Green Bank radio observatory, and we had to drive back to the telescope in a 1980s stick shift Volvo because the spark plugs in modern vehicles cause too much radio-frequency interference. Actually, I liked that Volvo. So maybe I wouldn't miss spark plugs."  
—Katie Peek, Information Editor

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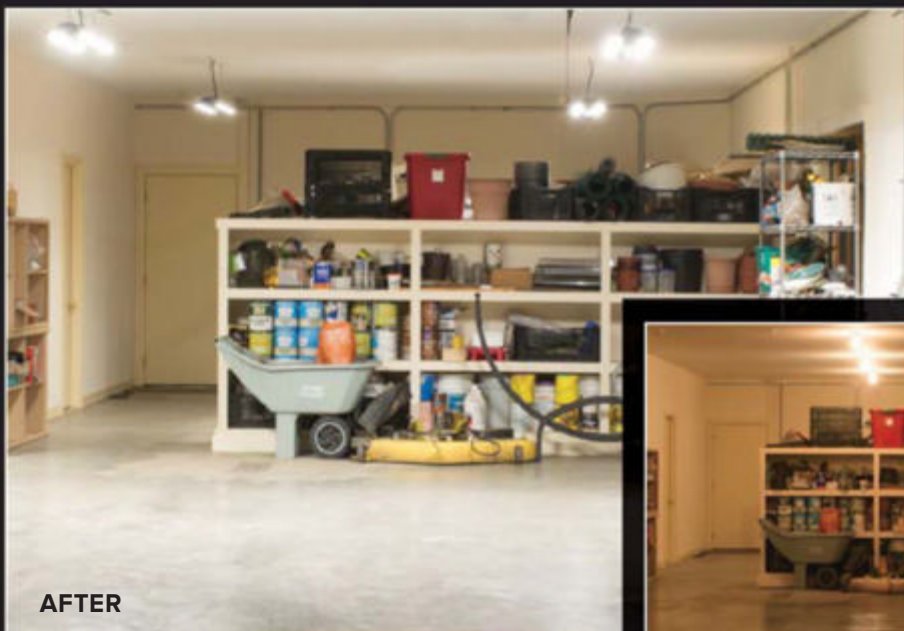
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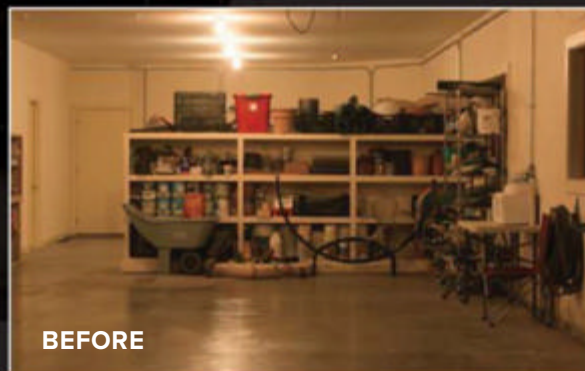


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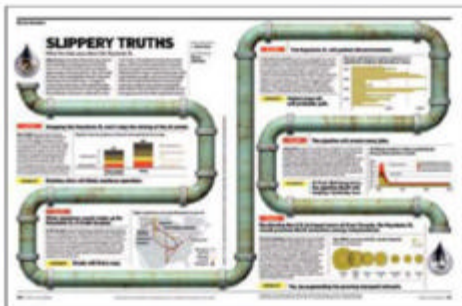


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## Peer Review



## SLIPPERIER TRUTHS

Many of you voiced additional concerns about the Keystone XL pipeline in response to the five we investigated in "Slippery Truths" [February 2015]. Information editor **Katie Peek** responds to a few of them.

**Darell Potter:** I would have liked to see how many miles the Keystone XL pipeline would add to the existing lines transporting oil and the total miles of all pipelines.

**KP:** There are something like 50,000 miles of crude-oil pipeline in the U.S. today, and the new Keystone XL segment would add about 800.

**Martin H. Crowe:** If it costs \$8 billion to build the pipeline, what does it cost to build a refinery closer to the source? Or along existing pipelines? It is likely less than \$8 billion and would avoid all the increased environmental risk.

**KP:** To manage the oil otherwise carried by the pipeline, a local refinery would need to process about 500,000 barrels daily. Andrew Leach, an energy policy expert at the University of Alberta, says \$8 billion would only cover the cost of a refinery capable of handling about 150,000 barrels a day. He points out that you'd still need pipelines to transport the refined product to market.

**Richard Payne:** One point of concern to the environmental community is the widespread damage being done to the wilderness areas where the mining is taking place.

**KP:** According to a 2014 report from the Alberta Biodiversity Monitoring Institute, 14 percent of the province's oil-sands region has been visibly affected by development. About a sixth of that impact comes from energy operations. In the area where oil-sands mining is digging up topsoil, the institute found almost no intact biodiversity.

### EMAIL SIGNATURE OF THE MONTH

**Sent from my Hyperloop cruiser at the fringes of a sparsely inhabited parallel universe.**

#### LIFE'S EXTREME POSSIBILITIES

When giant tube worms were first discovered around deep ocean vents, some thriving at hundreds of degrees Fahrenheit for hundreds of years, we realized life was more diverse and resourceful than we had believed possible ["Have We Found Alien Life?" February 2015]. We always assumed that life at least relied on the same chemistries. But what if there is a totally different chemistry at work deep in the Earth or Mercury or even the Sun that does not rely on atoms with electron shells? What if there are creatures whose "metabolism" is based on bare ions, immense temperatures and pressures, or even the kinds of crushing forces in neutron stars and black holes?

**Bill Dale**, Los Angeles

#### MISPLACED FEAR

In the February 2015 article titled "Striving for the Perfect Diet Is Making Us Sick," you note that anorexia is driven by a fear of being fat. This really misrepresents the disease. Someone who has anorexia has much more than a fear of eating. He or she has an inaccurate picture of his or her body and a disease-driven desire to make the body more "culturally acceptable."

**Robert R. Fluck Jr.**

North Syracuse, N.Y.



#### HAVE A COMMENT?

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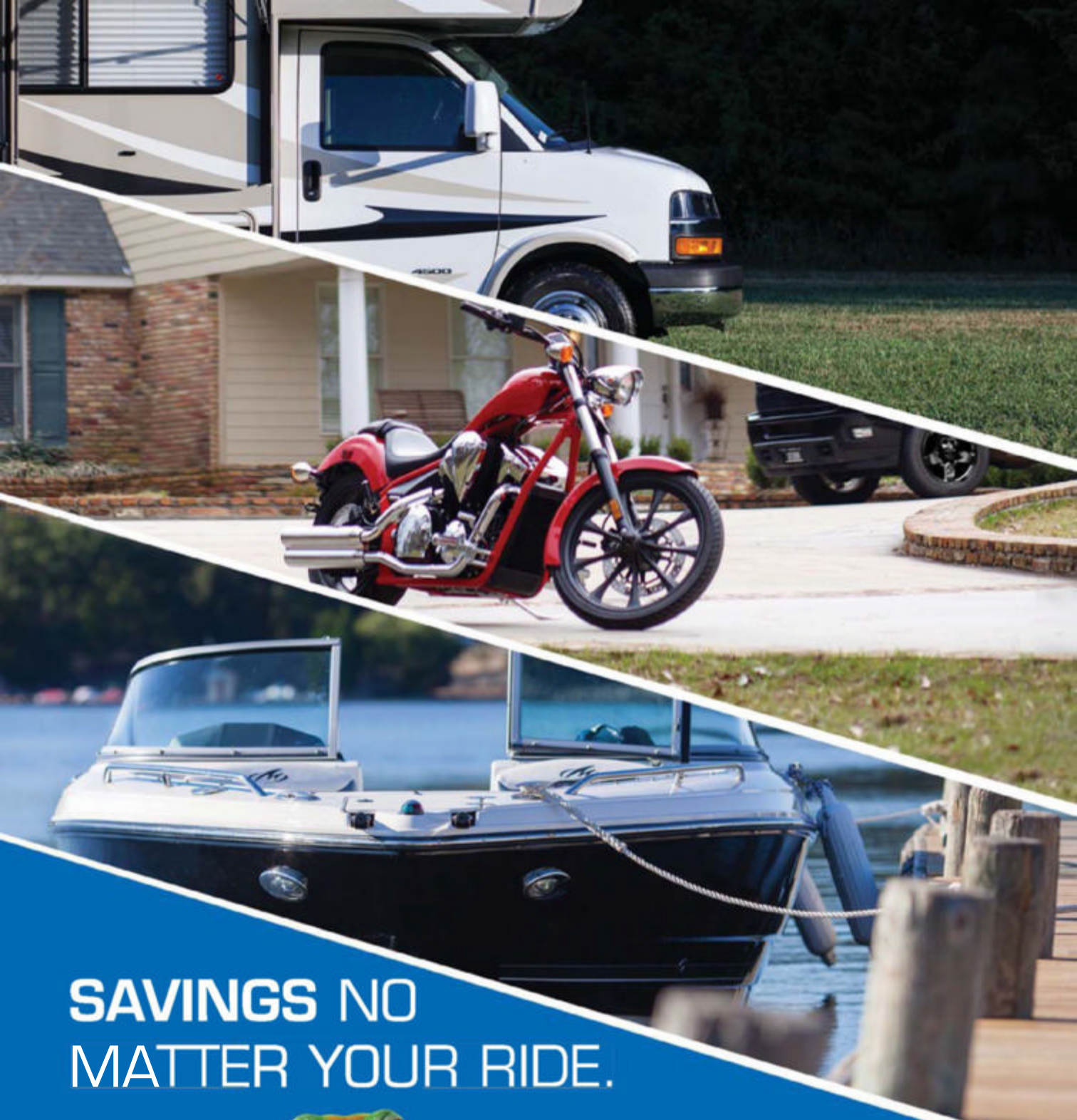


We asked about your worst jobs. **Ben Coats** of Ventura, California, wrote: "When I was 27, I got a job at a record company dialing Total Request Live on MTV (pressing redial over and over again, all day long) to request its big song. If you got through without a busy signal, which happened two to three times a week, you had to request the song 'Punk Rock Girl' by the Dead Milkmen [above] and keep redialing. The first time I got through, I gave an enthusiastic request. Then (hours later) the guy next to me gave a monotone 'Punk Rock Girl, Dead Milkmen.' I quit after a week."

### SEND US PICS!

**Show & Tell:** Electronics can have a fine life as intended, but it's more fun to give them a new calling. This month, we explore three ways to modify printers [page 66]. Send your favorite example of repurposed tech to [secondwindtech@popsci.com](mailto:secondwindtech@popsci.com) and include a picture!





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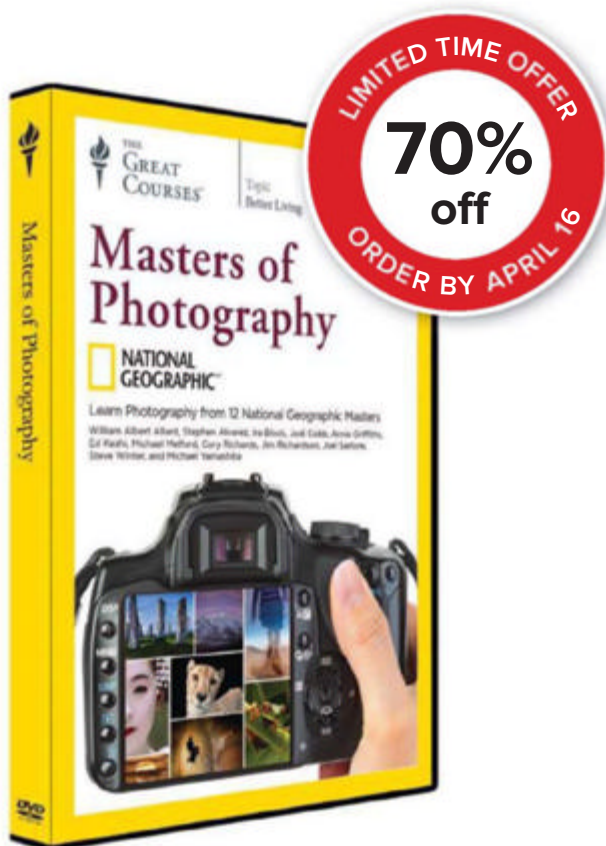
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# Now

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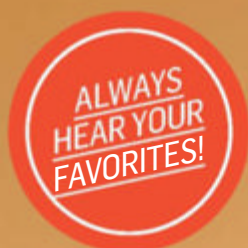
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**Not everyone** enjoys being a DJ. Many music fans just pick a playlist and leave it running. That's why Bang & Olufsen created a smart music-streaming hub to anchor its high-fidelity BeoLab 18 wireless speaker system.

The BeoSound Moment is a two-sided tablet and dock that plays songs it thinks you want to hear. The device learns your listening habits over time (like the fact that you rock out



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service

to Katy Perry on Sunday mornings) and creates custom mixes on the fly. The Moment selects tracks from the music-streaming service Deezer and its 35-million-song database, plus any audio files available on your home network. Smartphones and tablets can also connect to the Moment with Bluetooth, granting access to services like Spotify and YouTube.

Once set up, the Moment is easy to control. On one side of the device,

users can play, skip, or rewind a song and change the volume by tapping the world's first touch-sensitive wooden panel—which resembles an iPod's click wheel. On the other side, an LCD screen displays the B&O MoodWheel, a color wheel that represents different musical styles (red is up-tempo; blue is mellow). Users can select specific tracks using the LCD screen, too—but sometimes it's best to sit back and enjoy the mix. **MICHAEL NUÑEZ**

# American Muscle Reimagined

## 2015 CHEVROLET CORVETTE Z06

**Engine** 6.2-liter supercharged V8

**Horsepower** 650

**Fuel economy**

15 city/22 hwy (man.)

**Price** \$78,000

↓  
**For decades,** the Chevrolet Corvette tempted drivers with a simple proposition: lots of power in a light, well-balanced, and totally badass package. That was enough to make it one of the most iconic American cars ever built, rivaling any import on raw performance. Where the Vette lost to its European counterparts was in quality. **Essentially,** you got what you paid for.

In January, Chevy released the new Z06 and threw that equation out of whack. The car can run from 0 to 60 in less than three seconds, putting it in league with six-figure vehicles like the Ferrari 458 Italia, Porsche 911 Turbo S, and McLaren 650S. But where the Z06 **stands out** is in its finish. It **feels like a luxury machine.** And that's where it's truly disruptive. When drivers **can get** a vehicle with top-tier attributes at the fraction of the cost, what does that say about the future of sports cars? Advantage: America.

**MATTHEW DE PAULA**



## CAR NEWS YOU SHOULD CARE ABOUT

**1** General Motors' new OnStar Driver Assurance program anticipates when the battery, starter motor, or fuel pump might fail and warns drivers so they can fix problems before they occur. The service will be expanded to other parts in the future.

**2** In January, Juergen Peters, the president of car multimedia at Bosch North America, said that full windshield augmented reality could arrive within five years. The hitch? Automakers must fit a projector the size of a 12-pack of soda into the dashboard.

**3** A report from the environmental think tank World Resources Institute found that the production of biofuels such as ethanol is grossly inefficient. The report adds that land dedicated to biofuel production should be used to grow food instead.

**4** Volvo is working with Ericsson and POC to build a bicycle helmet that can communicate with cars. The helmet would send its location to the Volvo cloud network. When it senses that a Volvo connected car might hit a cyclist, both parties would receive a warning.

## DESIGN OF THE MONTH



### Volkswagen Golf R Touch

VW engineers are looking beyond the touchscreen. In the cabin of the Golf R Touch concept car, a series of cameras detect hand gestures. Drivers need only wave a hand to lower windows, open the sunroof, or control the main console. VW plans to roll out the gesture control features piecemeal in the coming years.

**1,000**

Target speed, in miles per hour, a British engineering team called the Bloodhound Project aims to reach during its land speed record bid in summer 2016





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# Obsessed

Some things are just ... better

LINDSEY KRATOCHWILL

## 1 THE THRILLING ADVENTURES OF LOVELACE AND BABBAGE

In her debut graphic novel, Sydney Padua imagines what might have happened if inventor Charles Babbage and Ada Lovelace (the first programmer) had actually built the first computer, which they conceived of in the early 1800s but never created. **\$29**

## 2 BOX

Bitdefender's BOX protects your smart home devices from hackers. It plugs into a router and protects connected devices at the network level. That way you don't have to download separate antivirus software for each operating system. **\$199**

## 3 SEAGATE SEVEN

If the name didn't give it away, Seagate's new 500GB solid state drive is just 7 millimeters thick. It draws power from a USB port (over a USB 3.0 cable), making external power sources unnecessary. **\$99**

## 4 STARTALK

National Geographic is turning cosmologist Neil deGrasse Tyson's radio program of the same name into a late-night talk show. Filmed in front of a live studio audience, Tyson continues the conversation about extraterrestrial life and space travel. **April 20**

## 5 ECHO 58V HEDGE TRIMMER

Echo's latest hedge

trimmer packs a powerful 58-volt lithium-ion battery. What's more, it's the first with anti-jam technology. When the blade senses snags, it reverses itself to clear debris. **\$269**

## 6 TI-84 PLUS CE

What has a USB port, a color screen, a battery that lasts for months, and brain enough to help you ace your math homework? The TI-84 Plus CE is Texas Instruments' first new graphing calculator in years. It's proof that even legends can get better. **Price not set**

## 7 EARTH: A PRIMER

Chaim Gingold—who worked on the game Spore—is turning digital textbooks into games. With the iPad app, users create glacial flows, sand dunes, and islands and in the process learn how forces shape the planet. **\$10**

## 8 ENERGIZER ECOADVANCED

Rechargeable batteries keep waste from piling up in landfills. But if that isn't your style, Energizer's new alkaline AA battery is made from 4 percent recycled battery material by weight and is the company's highest performing. **\$5 for 4**

## 9 WAGONTOP 4P

Any camping tent will provide shelter, but headroom? Not so much. NEMO Equipment's Wagontop 4P affords 6.5 feet of vertical space. Go ahead: Stand tall. **\$450**

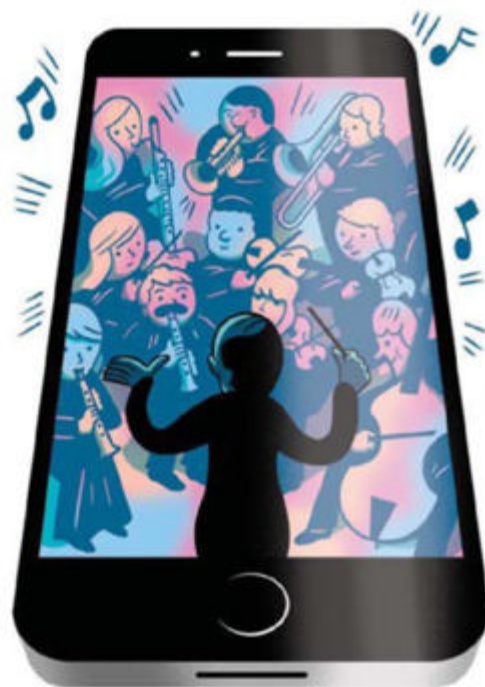


## 10 DELL VENUE 8 7000 SERIES TABLET

Not only is this tablet 6mm slim, it also includes Intel's RealSense Snapshot Technology, which uses depth mapping and three camera lenses. It also allows users to take virtual measurements and refocus images after they take them. Plus, it's strong. Trust us, we tried our best to break it. **From \$399**





**Testimonial**

## ORCHESTRA IN AN APP



### **If you've ever been**

behind the mic at a karaoke bar, you know the agony of a senseless backing track. Slow down your tempo for dramatic effect and the track blindly rolls forward. Speed up and the track stubbornly lags. Creative freedom is lost.

For decades, classical musicians have wrestled with the same problem. Many of them practice solos against backing tracks, and the inability to modify tempo can limit their creative expression. Cadenza, an orchestral accompaniment app developed at Harvard Innovation Lab, aims to change that by listening to soloists as they play and syncing the tempo of the backing track to them.

At the heart of the software, Cadenza uses pitch analysis to track where a musician is in the melody line and how his or her speed has changed in preceding measures. The algorithm uses that information to predict how the musician will play in upcoming measures.

"It brings a full orchestra into the study [room]," says Nicholas Kitchen, who plays violin in the Borromeo String Quartet and has recently started using Cadenza with students. "As a teacher, there is just layer upon layer being added to the learning." **JON CHRISTIAN**



### **CADENZA**

**Price** Free  
**Operating system requirements**  
iOS 8.0

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to be  
a bench.  
Recycle me."*



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BEAUTIFUL**



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**Standout**



**SAMSUNG JS9500**

**Size** 88 inches

**Screen** Curved

**Resolution**

3840 x 2160

**Smart OS**

Tizen

**2.5**

Number of times brighter an SUHD TV is than a conventional LCD screen

**NEXT-WAVE  
HIGH DEF**

# Finally! A 4K TV You Should Own

**Building a home** entertainment center is a lot like building a house: You need a solid foundation—and that's your television. If you're starting from scratch, you'll want a TV that will last more than five years, which means going with the highest-resolution screen available. Right now, that means buying a 4K TV. But there are a lot of different models (and gimmicks) out there. Happily, only one type really matters: the new Samsung SUHD TVs.

The new 4K TV line is one of the first to use nanocrystals, also known as quantum dots. When paired with blue light-emitting diode (LED) backlights, nanocrystals offer sharper contrasts, more accurate color, and brighter images than conventional LCDs. And because blue LEDs are cheap to make, nanocrystal TVs are markedly less expensive than organic LED (OLED) TVs—their main competitors in the 4K market.

Samsung's SUHD series includes flat and curved models in sizes between 48 and 88 inches. The TVs also have an eight-core processor to drive their new streaming-friendly operating system, which allows users to launch directly into Netflix or YouTube without a set-top box and to access PlayStation Now games without a console. That translates to fewer cables and less clutter—and a ridiculously easy setup.

**MICHAEL NUÑEZ**

## THE SECRET OF NANOCRYSTALS

**What they are:** Microscopic crystals tuned to emit precise colors when light shines through them.

**Why they matter:** Nanocrystals bring accurate, more lifelike color to affordable LED-backlit LCD TVs. For anyone ready to make the jump to 4K, nanocrystal TVs are the best place to start.

**How they work:** Standard LCD TVs use blue LEDs topped with yellow phosphor to create a white light, which shines through red, green, and blue filters. An SUHD TV shines blue light through nanocrystals and color filters. Without the phosphor, more light comes through—which makes them brighter.



## The Big Fix

# A SLEEVE TO SAVE PITCHERS' ARMS



## PROBLEM:

Hurling fastball, after curveball, after slider puts incredible strain on a pitcher's arm, which, over time, can cause painful tears in the ulnar collateral ligament (UCL). To make matters worse, pitching coaches can do little to predict the injury. They look at certain metrics—throwing speed and pitch count—to guess when a player's arm might be in overdrive, but those aren't all that accurate. Last year, for example, 30 Major League Baseball (MLB) pitchers were benched to undergo UCL reconstructions, dubbed Tommy John surgery after the first player to get it, in 1974.

## SOLUTION:

During spring training this year, more than 10 MLB teams began using the Motus mThrow motion-tracking system to keep tabs on pitchers' arm health. Players wear a 1.3-inch device with three gyroscopes and three accelerometers just above the elbow inside a compression sleeve. An app creates a 3-D model of the arm movement and calculates things like UCL torque and arm angle. Coaches get a snapshot of performance and alerts if signs of fatigue (say, a drop in elbow height) appear. More precise data helps coaches make arm-saving decisions such as pulling a pitcher when his arm needs rest. CORINNE IOZZIO



## MOTUS MTHROW

### Sensors

Gyroscopes, accelerometers

### Weight

14 grams

### Battery life

8 hours

### Price

\$170

After Tommy John surgery, pitchers are out of rotation for an average of one year.



## Too Much Innovation

# GO AHEAD, DRIVE OVER THIS COFFEEMAKER

Worried your coffeemaker might find its way beneath a pickup truck? Or get blasted by a water hose? Well, now there's the Oxx Coffeeboxx. Complete with an IP55 rating (which means it's protected from dust and water), the coffeemaker has an internal framework that can withstand a 1/4-ton load and a double-sealed water tank to prevent leaks. The machine brews single-serve coffee pods and is styled to fit in among power tools. Oxx founder and former Whirlpool designer Jim Doan says, "We had to build this from the ground up. It's not like any other appliance." Truer words could not be spoken. LINDSEY KRATOCHWILL





# THE DARK WEB REVEALED

Y

ou thought you knew the Internet.

But sites such as Facebook, Amazon, and Instagram are just the surface. There's a whole other world out there: the Deep Web.

It's a place where online information is password protected, trapped behind paywalls, or requires special software to access—and it's massive. By some estimates, it is 500 times larger than the surface Web that most people search every day. Yet it's almost completely out of sight. According to a study published in *Nature*, Google indexes no more than 16 percent of the surface Web and misses all of the Deep Web. Any given search turns up just 0.03 percent of the information that exists online (one in 3,000 pages). It's like fishing in the top two feet of the ocean—you miss the virtual Mariana Trench below.

Much of the Deep Web's unindexed material lies in mundane databases such as LexisNexis or the rolls of the U.S. Patent Office. But like a Russian *matryoshka* doll, the Deep Web contains a further hidden world, a smaller but significant community where malicious actors unite in common purpose for ill. Welcome to the Dark Web, sometimes called the Darknet, a vast digital underground where hackers, gangsters, terrorists, and pedophiles come to ply their trade. What follows is but a cursory sampling of the goods and services available from within the darkest recesses of the Internet.

MARC GOODMAN

## THINGS YOU CAN BUY

### 3 CLOUD COMPUTING

By hosting their criminal malware with reputable firms, hackers are much less likely to see their traffic blocked by less secure systems. A recent study suggested that 16 percent of the world's malware and cyberattack distribution channels originated in the Amazon Cloud.

### 4 CRIMEWARE

Less skilled criminals can buy all the tools they need to identify system vulnerabilities, commit identity theft, compromise servers, and steal data. It was a hacker with just such a tool kit who invaded Target's point-of-sale system in 2013.

### 6 HUMAN ORGANS

In the darker corners of the Dark Web, a vibrant and gruesome black market for live organs thrives. Kidneys may fetch \$200,000, hearts \$120,000, livers \$150,000, and a pair of eyeballs \$1,500.

### 5 HITMEN

Service providers—including a firm named for the H.P. Lovecraft monster Cthulhu—advertise permanent solutions to common problems. For everything from private grudges to political assassinations, these hired guns accept bitcoin as payment and provide photographic proof of the deed.

### 2 BULLETPROOF WEB-HOSTING SERVICES

Some Web hosts in places such as Russia or Ukraine welcome all content, make no attempts to learn their customers' true identities, accept anonymous payments in bitcoin, and routinely ignore subpoena requests from law enforcement.



This article was adapted from Marc Goodman's book **Future Crimes**, which was published in February.

## How to Access the Dark Web's Wares

### ANONYMIZING BROWSER

Tor—short for The Onion Router—is one of several software programs that provide a gateway to the Dark Web. Tor reroutes signals across 6,000 servers to hide a page request's origin, making clicks on illicit material nearly impossible for law enforcement to trace. It uses secret pages with .onion suffixes—rather than .com—which are only accessible with a Tor browser.

### SECRET SEARCH ENGINES

In mid-2014, a hacker created Grams, the Dark Web's first distributed search engine. Grams allows would-be criminals to search for drugs, guns, and stolen bank accounts across multiple hidden sites. It even includes an "I'm Feeling Lucky" button and targeted ads where drug dealers compete for clicks.

### CRIMINAL WIKIS

Carefully organized wikis list hidden sites by category, such as Hacks, Markets, Viruses, and Drugs. Descriptions of each link help curious newcomers find their desired illicit items.

### HIDDEN CHATROOMS

Just as in the real world, online criminals looking to obtain the most felonious material must be vouched for before they can transact. A network of invitation-only chatrooms and forums, hidden behind unlisted alphanumeric Web addresses, provides access to the most criminal of circles.

# THINGS THAT MAKE INTERNET CRIME WORK

## 1 DRUGS

Individual or dealer-level quantities of illicit and prescription drugs of every type are available in the digital underground. The Silk Road, the now-shuttered drug superstore, did \$200 million of business in 28 months.

## 2 COUNTERFEIT CURRENCY

Fake money varies widely in quality and cost, but euros, pounds, and yen are all available. Six hundred dollars gets you \$2,500 in counterfeit U.S. notes, promised to pass the typical pen and ultraviolet light tests.

## 3 FORGED PAPERS

Passports, driver's licenses, citizenship papers, fake IDs, college diplomas, immigration documents, and even diplomatic ID cards are available on illicit marketplaces such as Onion Identity Services. A U.S. driver's license costs approximately \$200, while passports from the U.S. or U.K. sell for a few thousand bucks.

## 4 FIREARMS, AMMUNITION, AND EXPLOSIVES

Weapons such as handguns and C4 explosives are procurable on the Dark Web. Vendors ship their products in specially shielded packages to avoid x-rays or send weapons components hidden in toys, musical instruments, or electronics.

## CRYPTOCURRENCY

Digital cash, such as bitcoin and darkcoin, and the payment system Liberty Reserve provide a convenient system for users to spend money online while keeping their real-world identities hidden.

## 5 HACKERS FOR HIRE

Organized cybercrime syndicates outsource hackers for hire. China's Hidden Lynx group boasts up to 100 professional cyberthieves, some of whom are known to have penetrated systems at Google, Adobe, and Lockheed Martin.

## 6 MULTILINGUAL CRIME CALL CENTERS

Employees will play any duplicitous role you would like, such as providing job and educational references, initiating wire transfers, and unblocking hacked accounts. Calls cost around \$10.



# Next

EDITED BY *Jen Schwartz & Breanna Draxler*







# 40.3

Projected speed, in miles per hour, of the Shanghai Tower's elevators—the fastest in the world



When the 2,073-foot Shanghai Tower opens this month, it will stand as the world's second tallest building, after the Burj Khalifa in Dubai. That makes it a prized summit for urban adventurers; Vadim Makhorov and Vitaliy Raskalov illegally climbed the unfinished structure—and the crane atop it—to get this shot. Engineering the 127-story tower was itself an enormous challenge. “Wind is the

biggest force on this building,” says Marshall Strabala, the project's chief architect. To combat it, he designed a uniquely shaped double-skin facade: The 137-degree rotation of the outer glass curtain wall cuts wind loads on the tower by 28 percent. “If you twist an airplane wing, it won't fly,” Strabala says. “That's the goal with a super-tall building: You have to make it un-aerodynamic.” JUNNIE KWON



# Jimmy Carter

## On Ridding the Planet of Disease

When President Jimmy Carter set out to eradicate guinea worm disease 30 years ago, it afflicted 3.5 million people in rural Asia and Africa. In 2014, that number had dropped to 126. The parasite, spread via stagnant water, grows and breeds in a person's body cavity before burrowing out of its host, causing tremendous pain. Guinea worm is on track to join smallpox as the second human disease ever to be expunged. The Carter Center's coup proves that, even without vaccines or treatments, we can wipe certain illnesses off the Earth. Today's faster, cheaper genomics will only hasten the elimination of future targets.



The biggest challenge in eradicating diseases is simply implementing what we already know. With guinea worm, you have to tell people to pour their drinking water through a filter cloth. But a lot of people with the parasite 30 years ago didn't have radios and couldn't read. It took two or three interpreters to get the information across. Now, even in poor countries cellphones are making that easier.

Sometimes misinterpreted science or politics cause setbacks. In 2003, states in Nigeria blocked us from giving polio vaccines. But when a three-foot worm is coming out of your face or sexual organs, it attracts attention. Guinea worm existed in 23,735 villages when we started. We've been to all of them. Now, for each person who has it, we know their name and how they got it. We're making sure it doesn't spread so that it might be completely gone in a few years.

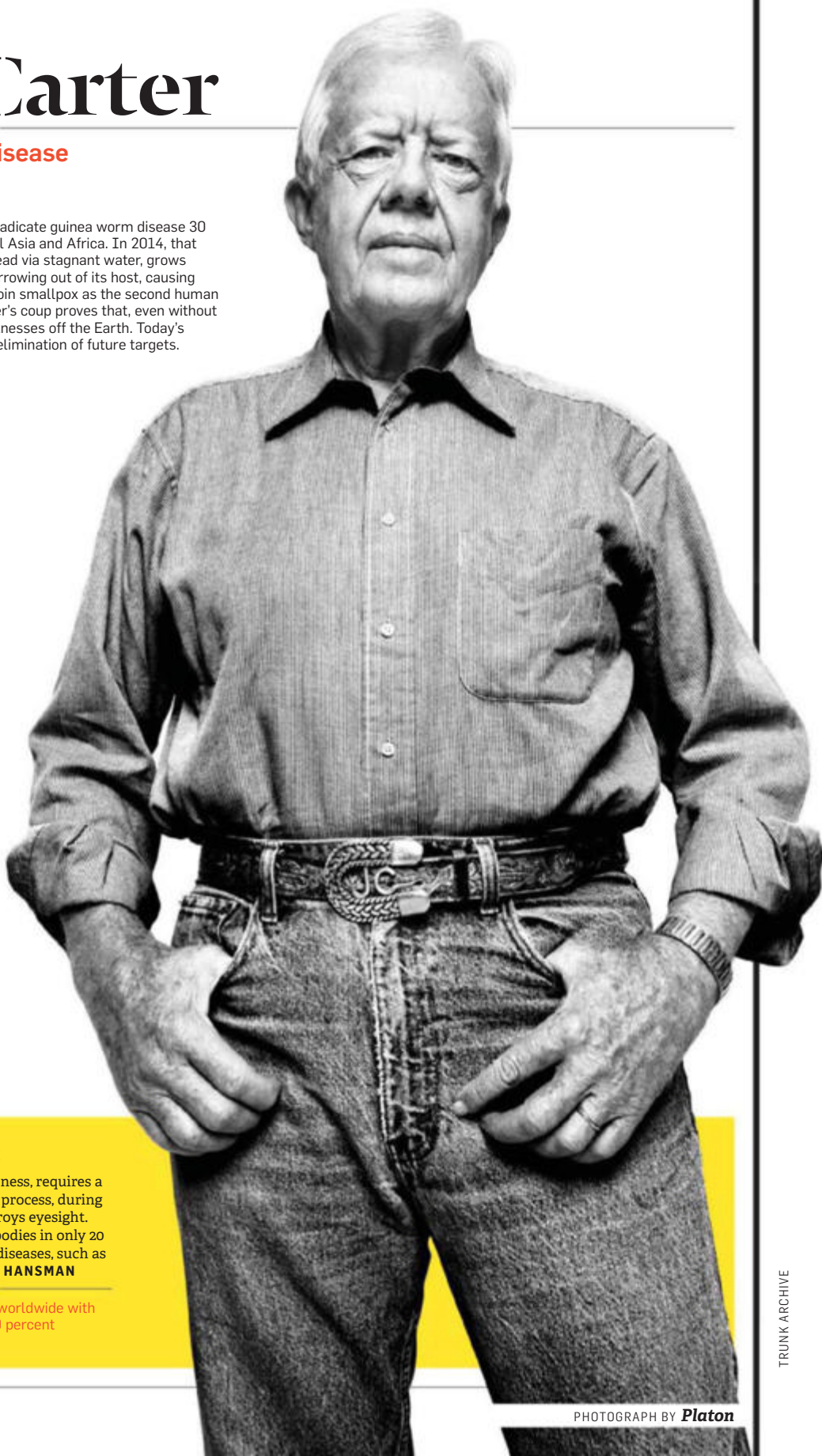
What we did with guinea worm is replicable. We've now gotten rid of river blindness in six countries in the Americas. If our task force determines it can be eliminated from the entire world, that will be our next major effort." AS TOLD TO JEN SCHWARTZ

### Up Next: River Blindness

Diagnosing *onchocerciasis*, or river blindness, requires a painful skin sample that takes months to process, during which time the parasite spreads and destroys eyesight. But a new blood test detects disease antibodies in only 20 minutes. Similar tests for other parasitic diseases, such as elephantiasis, are in the works. **HEATHER HANSMAN**

**25 MILLION**

Number of people worldwide with river blindness—99 percent of them in Africa







# Diamonds & Steel

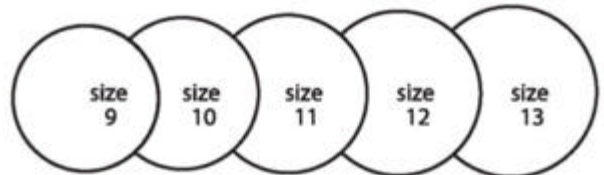
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**Concepts & Prototypes**

# A COMMUTER FERRY BUILT LIKE A RACING BOAT

**For all their** convenience, most commuter ferries are dirty machines. A high-speed one burns, on average, 6,600 gallons of fuel a day. Multiply that by the number of passenger boats on a busy waterway, like San Francisco Bay, and you've got a lot of spent diesel. Wind + Wing Technologies (WWT), a Napa, California, company, claims it can reduce that consumption by up to 40 percent.

WWT is developing a ferry that makes use of an abundant—and free—natural resource: wind. Instead of relying solely on engine power, specially designed catamarans will be equipped with vertical carbon-fiber “wing sails” similar to those introduced in the last America's Cup sailing race. Used in conjunction with an electric or clean diesel engine, the

**SAIL TO WORK!**

**1**

## WING

Each wing weighs about 4,000 pounds and is connected to the vessel by a 75-foot spine that turns freely. Three microphones measure audio signals from the wind. A computer then analyzes the readings to determine the wind's direction.

**2**

## TRIM TAB

Based on real-time wind direction, an actuator offsets the thin, outermost piece on the top of the wing by 15 degrees. This action forces the trim tab to move the wing, which provides thrust to the ferry, propelling it forward.

solar-powered wings automatically adjust position to capture the wind. And unlike traditional cloth sails, they require no expertise to operate, which has been a big stumbling block for wind-powered commercial vessels in the past.

The custom boats themselves will carry 149 passengers (and can be scaled up to carry 500). And while \$2 million for a pair of wings ain't cheap, WWT says they would likely pay for themselves in fuel savings in less than two years. The company has already run tests on a smaller 42-foot prototype vessel and is now in talks with public and private investors to service the route between San Francisco and Treasure Island. The project could be live by 2020.

**KATHERINE KORNEI**

**3**

## COUNTER-WEIGHT

A 200-pound lead beam balances the weight of the wing, making it sensitive to even tiny changes in wind direction.

**5**

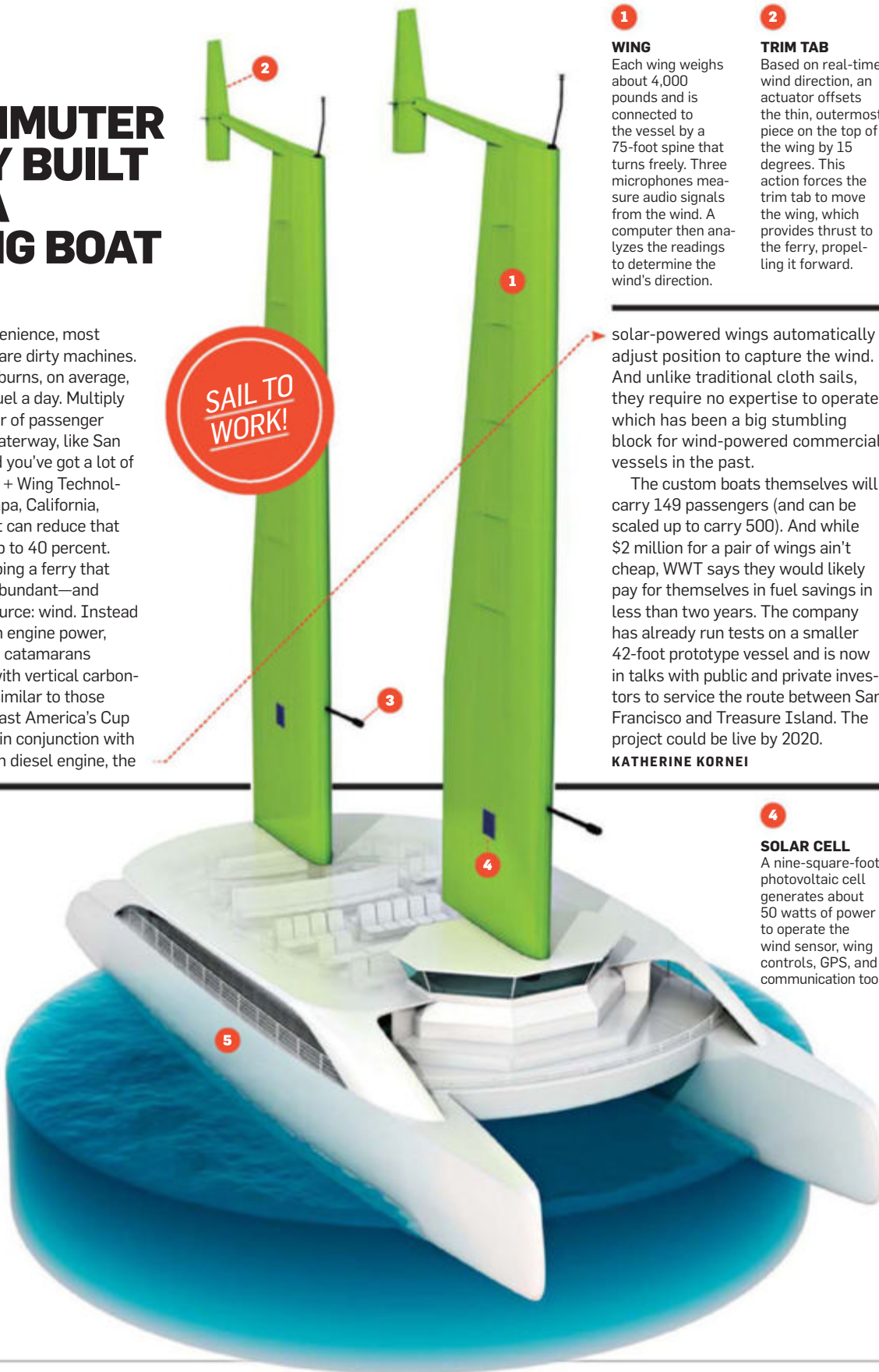
## BULKHEAD

Unlike traditional sailboats, these ferries need an interior bulkhead that runs the width of the catamaran. It will evenly disperse the wings' force on the boat—up to 72,000 pounds—between the two hulls to ensure stability.

**4**

## SOLAR CELL

A nine-square-foot photovoltaic cell generates about 50 watts of power to operate the wind sensor, wing controls, GPS, and communication tools.





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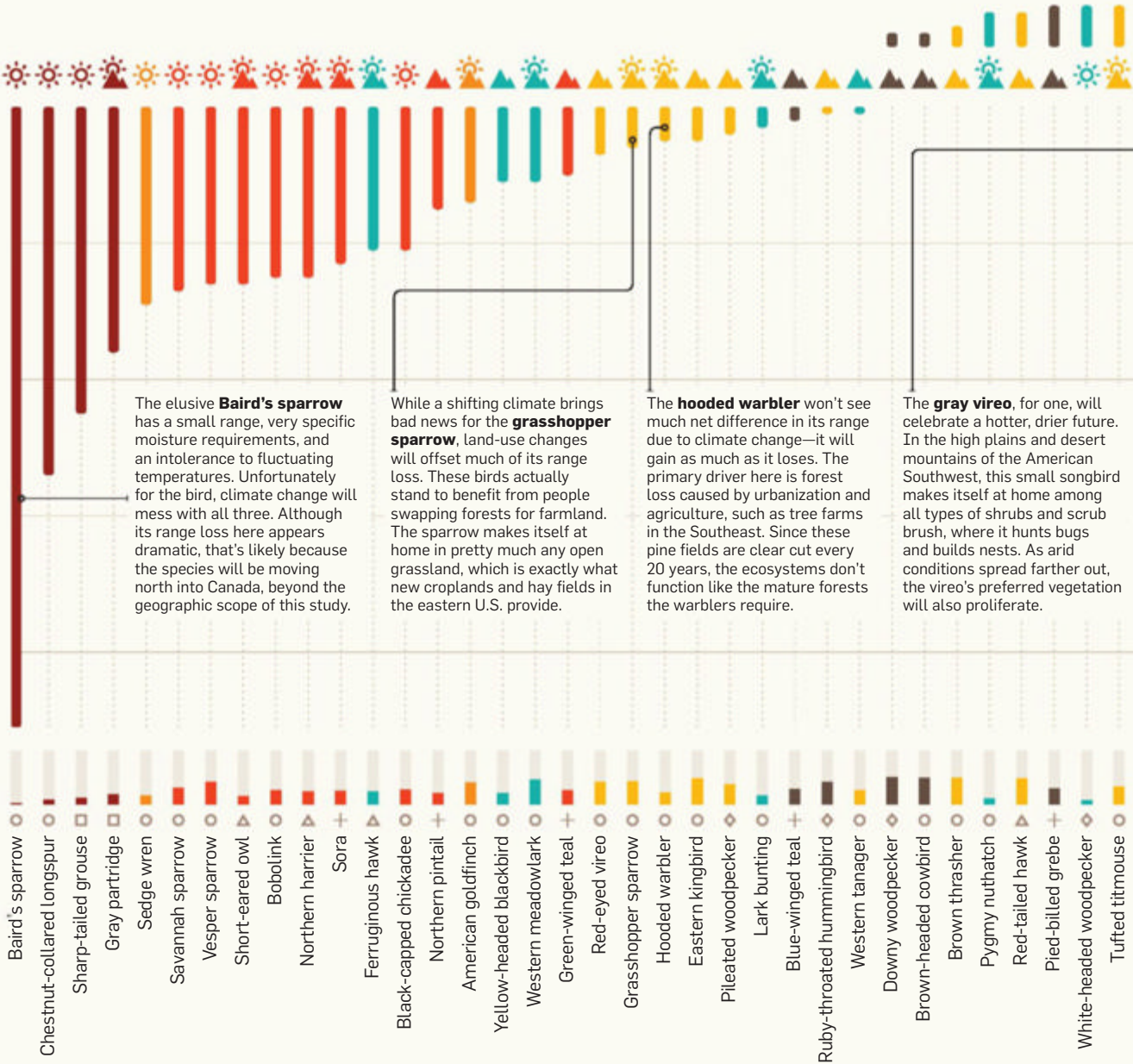
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RETRACTABLE AWNINGS

# A Birder's Guide to the Future

**Climate models predict** a much warmer world in 60 years, with flash storms and extended droughts. But they don't take into account changes to the land, like urban development, agricultural expansion, or resource extraction. "You're missing a very large part of the story if you don't look at the impact of land-use change," says Terry Sohl, a U.S. Geological Survey researcher. Sohl is the first to publish a study combining climate research and

high-resolution land-use data into a single model—in this case, to advance bird research. It shows how each species' U.S. range—the area where it can be found—will change by 2075. "Different species will respond to these shifts in different ways," says Wesley Hochachka, an ornithologist at Cornell University. "Some are tied to specific vegetation; some get along with humans; some are going to move. There will be winners and losers." **BREANNA DRAXLER**

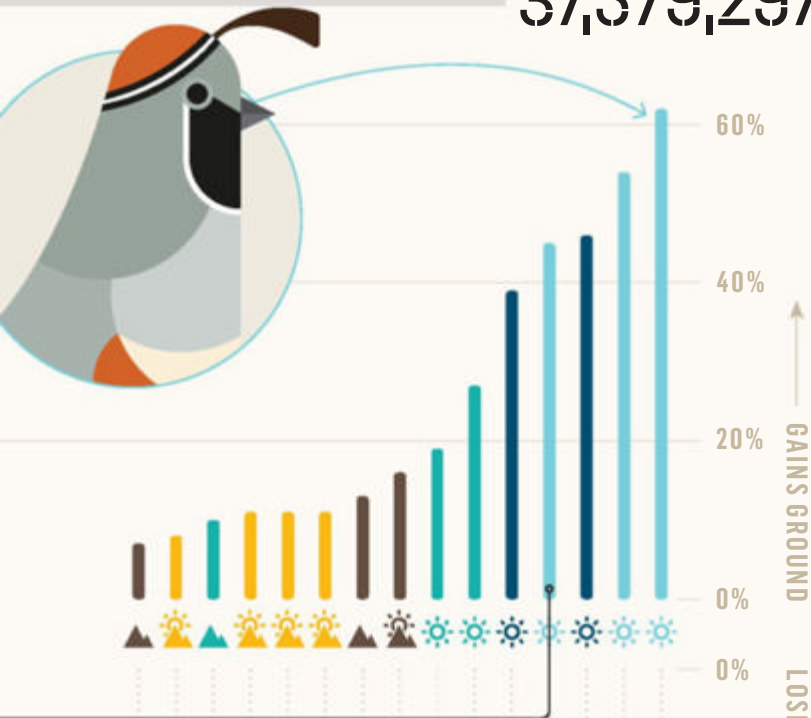
Quails in the Southwest have a taste for suburban life. As Phoenix and Tucson swell, these birds will likely settle in.





# 37,579,297

Number of U.S. bird observations entered into the eBird citizen science database in 2014. (Cornell's Sohl sifted through 2,319,910 of them to make his models for this study.)

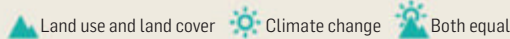


## HOW TO READ THIS VISUALIZATION

The graph shows how a bird's range—in the U.S. only—will likely change over the next 60 years. Color denotes the region a species calls home.

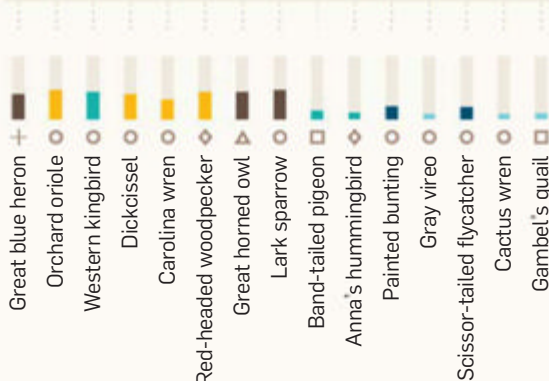
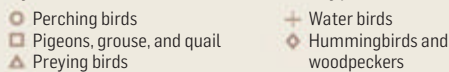


Symbols in the middle pinpoint the factor most responsible for the species' fate.



Bars along the bottom show the percentage of land in the lower 48 that is suitable habitat for each species.

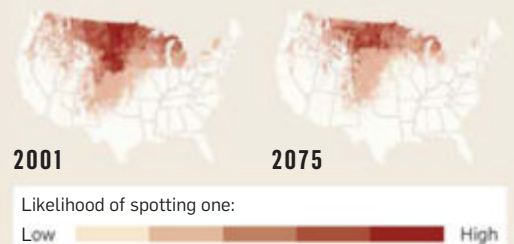
Symbols at the bottom show bird type



## CHANGE IN BIRD RANGE BY 2075

### SEX-DEPRIVED: SHARP-TAILED GROUSE

**Males are known** for their flamenco-like mating dance, for which they favor a very particular stage: an undisturbed, gently sloped hilltop with short (but not too short) vegetation that gives females a clear view. Frequent industrial hay harvests now jeopardize these critical mating grounds.



### INDIFFERENT TO US: GREAT HORNED OWL

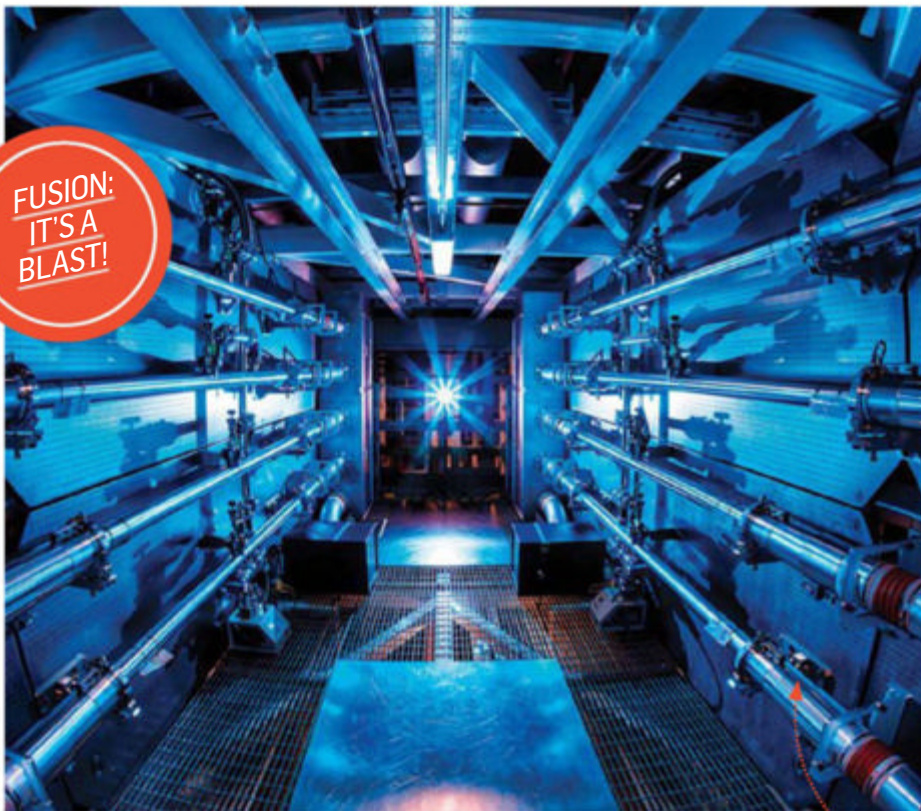
**Some species thrive** by not being picky eaters. These owls will go after anything they can find, including small mammals, reptiles, and even other birds. In fact, as long as there are enough places to nest, great horned owls don't seem to mind human company.



## NEW SURVIVAL TACTICS

**As species move** into different regions, they'll have to interact with new neighbors. In South Dakota, for example, northern mockingbirds are encroaching on brown thrasher territory. Soon they'll be competing for the same resources. Timing is an issue too. A European bird study found that species that began migrating earlier enjoyed stable or growing populations, while birds that stuck to the usual timetable saw declines. But the early birds face risks too. In response to warming temperatures, a species called the great tit has started laying its eggs sooner. Chicks hatch about 10 days before their primary food source, caterpillars, emerge. That's a problem. For the nonmigrators, behaviors may need tweaking. A study of the grey shrike-thrush in southeastern Australia found that the roadside-dwelling bird chirps at a higher frequency amid cars to ensure that its mating song can be heard over traffic.

Case in Points



FUSION:  
IT'S A  
BLAST!

# Three Ways to Make a Star on Earth

500

Output power, in megawatts, that ITER has been designed to produce, using only 50 MW of input power



**Last fall**, Lockheed Martin divulged a new fusion reactor design—one it claimed could power homes and cars in a decade. The wildly optimistic claim is reminiscent of that old trope: Fusion is just 10 years away ... and always will be. Still, experiments suggest we're getting closer.

Fusion is simple, in theory. You extract hydrogen isotopes from water and lithium and heat the fuel to millions of degrees (Celsius or Fahrenheit is irrelevant), creating the elusive fourth state of matter: plasma. The nuclei then move faster and faster until they collide and fuse, forming helium and releasing energy. *Et voilà!* Limitless clean power.

In practice, it's not so easy. Unless the plasma is constantly squeezed and heated, forcing the nuclei together, the reaction diffuses into

nothingness—it's very difficult to contain something akin to the center of a star. Nonetheless, today more than a dozen teams are racing to create a sustainable fusion reaction. These three strategies lead the charge. **SHANNON PALUS**

1

## Massive magnets to confine plasma

This year, construction will begin on the 35-nation megaproject ITER, located in France. A doughnut-shaped, power-plant-size reactor, ITER will contain a fusion reaction within a magnetic field and siphon off energy through its metal walls. Scientists hope to have a test-scale reaction running within the next decade.

2

## A reflective wall in a compact reactor

In Lockheed's design, a row of magnetic coils create a reflective wall to contain the plasma. The company's small-scale reactor allows scientists to tweak experimental setups more nimbly than they can with a reactor the size of ITER. Lockheed says it has already fired up its reactor 200 times but won't release any data—so whether those attempts were successful remains to be seen. If they were, well, we may all be driving literal Ford Fusions before long.

3

## A micro-explosion ignited by lasers

At the National Ignition Facility, scientists approach fusion differently. They fire dozens of lasers at a BB-size bead of solid deuterium and tritium. In a billionth of a second, the hydrogen-based fuel collapses into a dense plasma and bursts into a puff of energy. Last year, scientists produced the first-ever net positive fusion reaction, meaning they got slightly more energy out of the plasma than they put in.

## DEAD ENDS IN THE SEARCH FOR LIMITLESS ENERGY

Leonardo da Vinci once declared **perpetual motion machines** poppycock, on par with alchemy. But that was only after he tried to make one. His notebooks are littered with failed attempts.

In 1989, chemists Martin Fleischmann and Stanley Pons claimed to have achieved **cold fusion**, a room-temperature fusion reaction, with cheap lab supplies. But no one has been able to re-create it.

Medical doctor Randall Mills alleged in 2005 that he had created **hydrinos**—hydrogen fuel with 1,000 times the energy of coal. But their very existence, physicists argue, would violate the laws of quantum mechanics.



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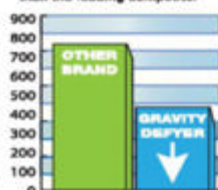


Medium Widths  
□ BLUE TB9004MUS  
■ GREY TB9004MGS  
■ BLK/RED TB9004MBR

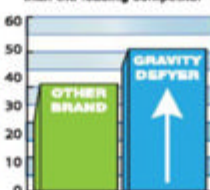


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## Decoded

# SHOULD YOU TRUST BIG PHARMA WITH YOUR DNA?

Privacy is a small price to pay for personalized medicine



**In January**, the biotech company Genentech reportedly committed \$10 million for access to the DNA of 3,000 Parkinson's patients and their families. A week later, Pfizer made a similar deal for the genomes of 5,000 people with lupus. At least 11 more similar transactions are on the way—deals in which the private genomics company 23andMe stands to profit by commodifying its customers' biological identities.

Off the bat, that sounds pretty creepy: offering up genetic information to the highest bidder. It's sort of like what Google does with your whereabouts and searches. The thing is, selling or volunteering personal information may just transform medicine. A trove of data could give scientists the tools they need to develop gene-specific drug therapies for certain diseases. "We are hoping to ultimately develop Parkinson's medicines, for example, that actually modify the disease as opposed to just treating symptoms," Genentech's Nadine Pinell says. Analyzing patterns in DNA could also help scientists find the genetic markers that trigger diseases, making preventive care more individualized and effective.

Even the White House is getting on board. In February, President Obama announced the \$215-million

# 141

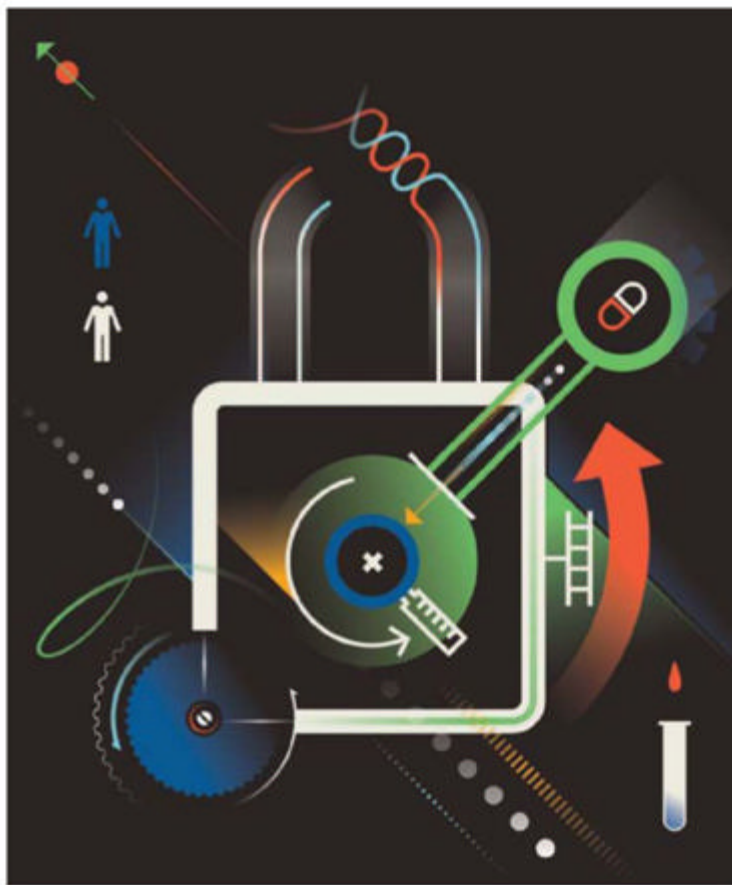
The economic return in USD on every dollar the federal government invested in the 17-year Human Genome Project

Precision Medicine Initiative, which aims to compile genetic information from one million volunteers. "Ultimately," Obama said, "this has the possibility of not only helping us find new cures, but it also helps us create a genuine health care system as opposed to just a disease care system."

As with any modern data business, privacy is a concern. Even a small segment of DNA (23andMe looks at 750,000 base pairs out of 3 billion) can reveal a history of illness or predict future risks and be used, Maury-style, to identify baby daddies. But Dave Kaufman, program director at the National Human Genome Research Institute's Division of Genomics and Society, says those worries are far-fetched. Research materials remain anonymous and closely guarded—

although data breaches, like the one in February suffered by health insurer Anthem, punch a hole in consumer confidence. Legislation offers some protection, too: The 2009 Genetic Information Non-discrimination Act makes it illegal for employers or health insurance companies to discriminate based on genetic data. The Act doesn't address who controls data once it's out there, but more policy is sure to arrive soon. And the White House initiative will certainly have plenty of security experts on the payroll.

Perhaps the most compelling reason to embrace DNA-sharing is that people don't seem all that distressed about giving up their data. Eighty percent of 23andMe's users have already opted to make their genomes available for studies. Whether they understand the fine print on what they're signing away is up for debate. But most people, especially those with genetic disorders in their families, probably know they have more to gain from potential discoveries than they have to lose from unlocking their biological identities. **HEATHER HANSMAN**



**"This has the possibility of helping us create a genuine health care system as opposed to just a disease care system."**



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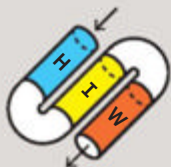
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# 10th Annual How It Works

ISSUE

The World's Most Awesome Vehicles, Tools,  
and Toys, Dissected and Demystified

Low-profile tire

Rear axle

Swing arm

Carbon-fiber-reinforced belt drive

## SUSPENSION

With so much power, the Slingshot needs a suspension that can handle turns without giving passengers a racecar-like beating. Gas-filled shocks, forged aluminum, double-wishbone suspension up front, and a hollow, cast-aluminum swing arm in the rear ensure it rides comfortably. An anti-roll bar, which links the wheels to the chassis, keeps the car flat in the corners, so there's minimal roll.



# THREE-WHEELED SUPERCAR



**New classes of vehicle** don't come along all that often, which is why the Polaris Slingshot stands out among this year's launches. The three-wheeled moto roadster draws from the company's experience with

both off-road ATVs and on-road motorcycles to create something unique: a high-performance two-seater that starts at \$20,000 and corners like a Ferrari.

The project began simply enough. Polaris wanted to attract thrill-seeking drivers who have no

access to off-road trails (i.e., city dwellers). But actually building the Slingshot proved complex. The engineers had to develop a well-balanced machine with a light-weight chassis and a single-wheel rear-drive system. Even then, the launch didn't go smoothly. The company recalled the first 1,800 vehicles in January to replace faulty ball bearings in the steering rack.

Legally, the Slingshot is deemed a motorcycle (operators need a motorcycle license). But for anyone behind the wheel, it's clear that it is much, much more. **ERIC ADAMS**

1

## ENGINE

A 2.4-liter General Motors Ecotec engine delivers 174 horsepower, a tremendous amount for a vehicle that weighs just 1,700 pounds. That power is transferred to the 20-inch rear wheel by a carbon-fiber-reinforced belt, and drivers control the transmission with a five-speed manual gearbox—an increasingly rare perk in cars.

2

## CHASSIS

The vehicle's low, wide stance—it's 77.6 inches across—helps maintain a low center of gravity. The stiff high-strength-steel frame further enhances stability. The effect is so thorough that after a few miles drivers will forget that they're not on four wheels.

3

## WHEELS

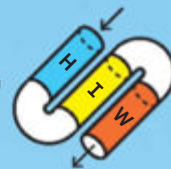
The low-profile performance tires minimize sway and maximize grip. Weight distribution is identical on all three wheels, which is a challenge for a vehicle that lacks the conventional rear mass of a four-wheel car. Too light a rear end and you could spin out on fast corners. To further reduce that risk, designers equipped each wheel with antilock brakes, traction control, and electronic stability control.

4

## COCKPIT

Because the cockpit is open, Polaris has weatherized it with motorcycle-grade materials. The company also combined the best features of a car and motorcycle: a media center with a backup camera, a Bluetooth-enabled sound system, and, best of all, twin front seats.





# SELF-TRACKING DRONE

The Zano flying camera is a great tool for snapping pictures of yourself—and it's far more sophisticated than a selfie stick. The \$300 quadcopter uses a suite of instruments to dodge obstacles while autonomously tracking its subjects,

whether they're walking through an office, biking down mountain trails, or even diving off cliffs. Lead engineer Ivan Reedman of Torquing Group advises against underestimating Zano's abilities: "It's not just a selfie drone." **GREGORY MONE**

## 1 REMOTE CONTROL

Zano connects to a user's smartphone via Wi-Fi. Users can pilot the drone using a virtual joystick on their smartphone screen; they can adjust its altitude via a simple slide bar; and they can instruct the camera to stay fixed or rotate to capture different views.

## 2 TRACKING OUTDOORS

In follow mode, a user sets the drone to trail the phone at a fixed distance. Outdoors, Zano establishes and sustains its position relative to the phone using GPS, gyroscopes, accelerometers, sonar, and a barometric pres-

sure sensor that helps it estimate altitude. "Even if you're moving, Zano will maintain its focus on you," says Reedman.

## 3 OBSTACLE AVOIDANCE

Infrared sensors prevent Zano from crashing into obstacles, but Reedman and his team also designed the drones so they won't run into one another. Every Zano has a unique identification number, along with a small low-frequency radio. If one approaches within 150 feet of another, they will recognize each other via radio and adjust their flight paths accordingly.

## 4 INVISIBLE TETHER

To maintain its Wi-Fi connection and comply with aviation regulations, the drone never drifts outside a predetermined maximum distance from the user's smartphone. "If it gets out of range, it will either land or go to where you were last," Reedman says.

## 5 INDOOR AUTONOMY

Inside, GPS is unreliable, and a slammed door is enough to throw off the barometric sensor, so Zano relies on other techniques. A sonar constantly pings the floor, gauging the drone's height, and five infrared

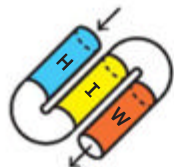
transceivers bounce signals off the walls and ceiling. The device's microcontroller parses this data a thousand times per second to determine whether Zano is in the right position—or heading for a wall.

PALM-SIZE PILOT



If you really plan to jump off a cliff with a smartphone, at least use a waterproof case!





In July 2014, Facebook acquired Oculus VR for a value of \$2 billion.

# VIRTUAL REALITY

After three years of development, the Oculus Rift—the most advanced virtual reality (VR) headset ever created—is nearly ready for its consumer release. The Rift is hardly the first VR headset (remember the Nintendo Virtual Boy?), but it's set to succeed where others failed. Today's displays are sharper and smaller, the processors are more powerful, and the head-tracking sensors are more

accurate. For users, that translates into more immersive experiences from a more compact device.

The first VR demonstrations will probably be games. Imagine titles that plunge players into realistic war zones or rich Tolkien-inspired worlds. But VR's true impact will only become clear later, when artists, filmmakers, researchers, and educators begin to use it in ways no one has thought of yet. Palmer Luckey, the co-founder of Oculus VR, and Nirav Patel, an engineer at Oculus VR, gave *Popular Science* a crash course on the principles behind the platform.

**MICHAEL NUÑEZ**

1

## LENSES

Establishing a focal point is critical to perceiving depth. "You're looking at a virtual image plane in each eye," says Patel. In essence, the user's eyes are staring beyond the display and into the virtual environment.



Display

Tracking technology

## DISPLAY

A high-resolution screen that sits just a few inches from a user's eyes projects a stereoscopic image—or two warped images on each half of the screen. "We're just using the normal way that humans use binocular vision to perceive depth," Patel says. "There are horizontal offsets between objects visible in the left and right eyes, which the visual cortex can process to perceive depth." In other words, when the warped 2-D images are viewed in close proximity, users are tricked into believing they're standing in a virtual world.

2

## TRACKING TECHNOLOGY

The headset comes equipped with more than a dozen sensor inputs. For example, a gyroscope, accelerometer, and compass track the location of a user's head. Designers also added external infrared sensors

and a camera to increase positional accuracy and monitoring. Software running on a nearby host PC analyzes that data and renders images of a virtual world that adapt to head position. Luckey says that the system's low latency enhances realism.

3

## 3-D AUDIO

To be fully immersive, you need great sound, and Oculus has some of the most spatially accurate. "All you need is to simulate two microphones in the game, and you can simulate audio in the real world," Luckey says. But the truth is that

the software is slightly more sophisticated. "We can generate a good approximation of what each ear should hear at its location in virtual space," says Patel, "which is much better than what you could do with a typical surround-sound setup."



# DEATH BY BLACK HOLE

As you fall feet first across an event horizon—the point where nothing can escape the black hole's gravitational pull—you don't feel anything change. But eventually, gravity is so much stronger at your feet than your head that you're stretched apart, like Play-Doh, until you snap. Or at least, that's the picture physicists drew after Einstein proposed his theory of general relativity in 1915. In the past few years, new possibilities for your untimely end have emerged.

The thought experiments attempt to resolve a paradox that physicist Stephen Hawking outlined in the 1970s. He showed that in their current forms, the two major pillars of physics—quantum mechanics and general relativity—can't both be true near a black hole. General relativity governs how very massive objects work, while quantum mechanics governs how very tiny objects work. In most of the universe,

physicists can choose which set of rules to apply—general relativity for a galaxy cluster, quantum mechanics for a particle accelerator—but a black hole is both very massive and very small.

And that's what makes this riddle so interesting. If physicists can answer the question of death by black hole, they'll be much closer to merging the two pillars into a single theory of quantum gravity, says Joe Polchinski, a theoretical physicist at the University of California at Santa Barbara who's working on the problem. "Ultimately, we're looking for a theory that unites the forces of the universe." **KATIE PEEK**

1

In the traditional picture, you fall into the black hole until gravity is so warped that it stretches you out like spaghetti.

Event horizon

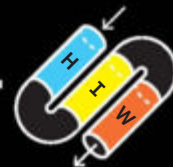
2

But if there's a firewall, as soon as you cross the event horizon, you're incinerated by a wall of energy.

## NOT YOUR GALAXY'S BLACK HOLE

The light-sucking singularities described here are theoretical, not the very real super-massive black holes that lie at the center of the Milky Way and other big galaxies. These quantum black holes need stable, isolated environments. Plus, their quantum-mechanical properties can take longer than the age of the universe to appear. That means there's no chance of testing many of the death-by-black-hole theories experimentally, says Don Page, a theoretical physicist at the University of Alberta who worked with Hawking. "They develop so late there wouldn't be people left to test them. Of course, you'd be kind of crazy to fall into a black hole anyway."





## THE INFORMATION PARADOX

**The current debate** revolves around how black holes handle entangled particles—entities whose properties are quantum-mechanically linked—when one of them falls across the event horizon. It's akin to considering a human's fate, but more intriguing to physicists. You can think of the particles as a pair of dice where when one is rolled, the other magically rolls itself so the sum of the two is always seven. Each particle can only be linked this way to a single partner—physicists call them “monogamous.”

### 1 Traditional View

**THE PICTURE:** According to general relativity, nothing can escape black holes, so they should only get bigger over time as they swallow up detritus. But in the 1970s, Stephen Hawking pointed out that thanks to a quirk of quantum mechanics, matter actually can escape. Quantum mechanics says pairs of particles constantly pop into existence and immediately self-annihilate. When a pair forms at the event horizon, one can fall into the black hole while the other drifts off instead of disappearing. That particle effectively carries some matter away, and eventually, the black hole will evaporate entirely.

**THE FLAW:** This small quantum mechanical effect—dubbed Hawking radiation—has big implications that physicists are just now puzzling out. Those particles are linked like the magic dice that always add up to seven. Once the surviving particle loses its partner across the event horizon, it would link itself to a new one. But according to relativity, the particle inside the event horizon doesn't know anything's changed, so it still thinks it's happily linked to its partner. There's a monogamy problem, because the surviving partner can't be linked both to a new particle and the old one.

### 2 Firewall View

**THE PICTURE:** In 2012, researchers at the University of California at Santa Barbara proposed a solution to the monogamy problem. What if the surviving partner gave up its entanglement with its original partner when that particle disappeared across the event horizon? The divorce would keep quantum mechanics happy. A firewall would develop just beyond the event horizon because each breaking link would create a little burst of energy, like a breaking chemical bond. Collectively, the energy makes a wall of fire that would incinerate anything that fell across the event horizon.

**THE FLAW:** To construct the firewall, physicists had to abandon one of the original properties of a black hole: that an observer falling across the event horizon feels nothing change—a principle colorfully known as “no drama.” The firewall rankles many physicists, but most agree that the scenario is useful for teasing apart the subtle problems quantum mechanics causes for black holes. Polchinski, one of the authors of the firewall paper, agrees that they probably aren't the final answer. “Odds are the original picture is still right,” he says. “Even though we don't know why.”

### 3 Wormhole View

**THE PICTURE:** A pair of physicists at Princeton and Stanford proposed another possible solution. What if, they posited, the surviving particle's two partners—the old one inside the event horizon and the new one outside it—were actually the same particle? What if the swallowed partner encountered a wormhole inside the black hole that allowed it to pop out somewhere else? The surviving particle could link up with it, thinking it's found a new partner, while the swallowed particle wouldn't notice anything had changed (apart from finding itself in a different part of the universe).

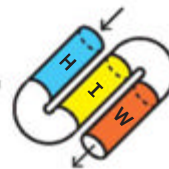
**THE FLAW:** The wormhole offers a seemingly clean solution to the paradox. “It's a bit like a B movie where you never see person one and person two together, so they must be the same person,” says Raphael Bousso, a physicist at the University of California at Berkeley. But the caper may be impossible to pull off, because the approach conflicts with quantum mechanics in other ways, Bousso says. “I don't find it as promising as others do.” So the debate continues.

3

Or, a wormhole at the black hole's center may whisk you unscathed\* to another part of the galaxy.

\*Well, if you're a particle. Humans wouldn't actually emerge unscathed.





# HYDROGEN VEHICLE

**In the past year**, three automakers—Toyota, Honda, and Hyundai—have debuted new hydrogen cars. The biggest launch is likely the Toyota Mirai, which will hit U.S. streets this fall. Fuel cell vehicles (FCVs) have for years been the white whales of the clean-vehicle

set. They emit only water; they fill in three minutes (vs. up to several hours for a traditional electric); and their range is comparable to gas-powered cars, about 300 miles. But automakers have avoided them, mainly because of infrastructure concerns: There are only a dozen hydrogen filling stations in the U.S., mostly in Southern California. That, too, is changing. Last year, the state set aside \$200 million to build 100 more hookups by 2020. And that just may drive a national trend.

**NICK DAVIDSON**

1

## HYDROGEN TANK

Two carbon-fiber tanks store 11 pounds of hydrogen fuel under very high pressure (10,000 psi). In emergencies (e.g., a crash), sensors trigger shutoff valves to keep hydrogen from escaping the tank.

2

## AIRFLOW

The intake grill sends oxygen—a crucial component in the mix—to the fuel cell stack.

3

## POWER CONTROL UNIT

As the car's energy manager and brain, the power control unit draws electricity from the fuel stack and sends it to the motor. During acceleration, it draws stored energy from the battery for an extra boost.

4

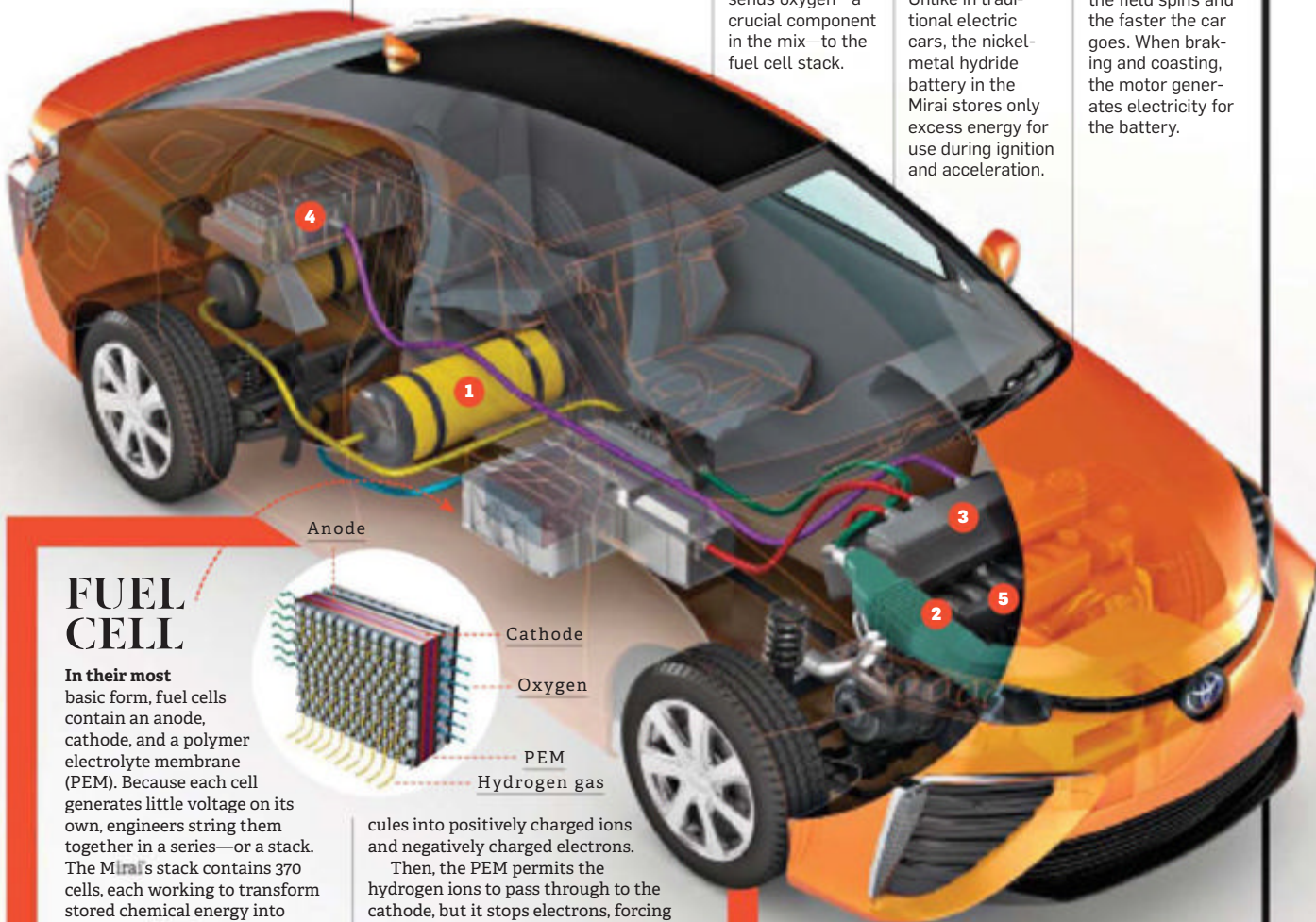
## BATTERY

Unlike in traditional electric cars, the nickel-metal hydride battery in the Mirai stores only excess energy for use during ignition and acceleration.

5

## ELECTRIC MOTOR

As electricity passes through the motor, it polarizes the stator—a stationary ring around the rotor—to create a rotating magnetic field. Magnets mounted on the rotor align with that field and spin at the same rate to power the drivetrain. The more electricity that's sent to the motor, the faster the field spins and the faster the car goes. When braking and coasting, the motor generates electricity for the battery.



## FUEL CELL

**In their most basic form**, fuel cells contain an anode, cathode, and a polymer electrolyte membrane (PEM). Because each cell generates little voltage on its own, engineers string them together in a series—or a stack. The Mirai's stack contains 370 cells, each working to transform stored chemical energy into electricity. **Here's how.**

In each cell, hydrogen runs through a flow field plate to the anode. There, a platinum-cobalt catalyst splits the hydrogen mole-

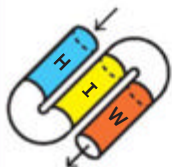
cules into positively charged ions and negatively charged electrons.

Then, the PEM permits the hydrogen ions to pass through to the cathode, but it stops electrons, forcing them instead to travel an outer circuit, creating an electric current.

**Finally**, electrons and ions meet up with oxygen at the cathode to form water, which is emitted primarily as vapor.

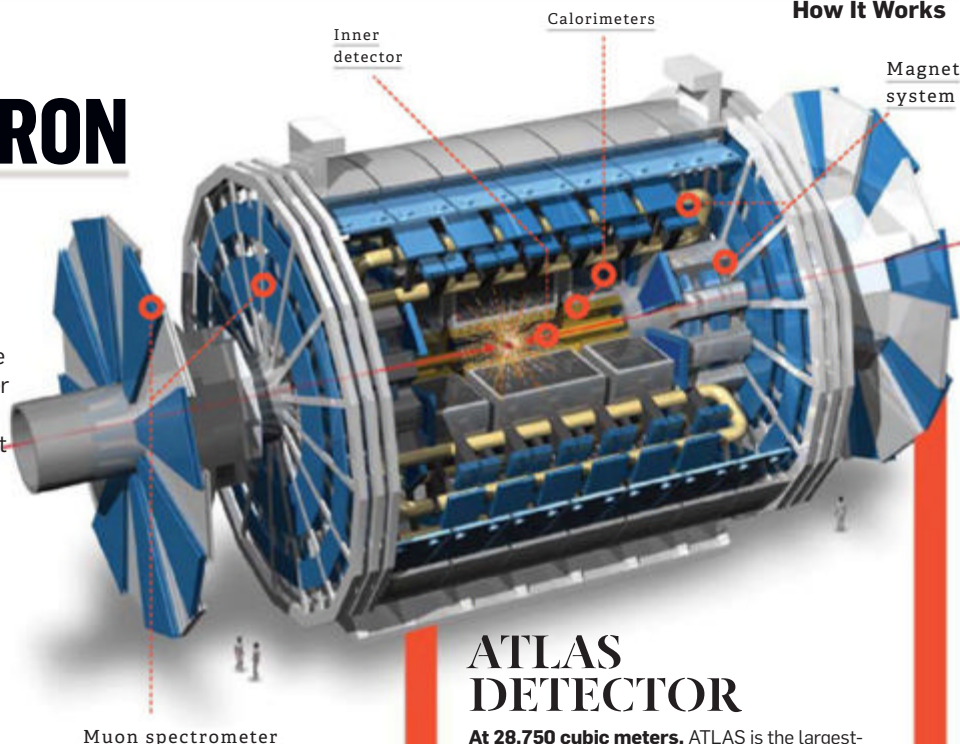
The Toyota Mirai arrives in Southern California this fall.  
Suggested retail: \$57,500





# LARGE HADRON COLLIDER

**The world's most** powerful particle accelerator, the Large Hadron Collider (LHC), famously upended physics with the discovery of the long-sought Higgs boson in 2012. But it was only operating at half power. Since then, the LHC has undergone a massive upgrade, and this spring, it will ramp back up for a second run at near full strength. For the next three years, more than 12,000 scientists will use the LHC to explore the deepest and weirdest questions in particle physics. What they will find—new particles, forces, or even dimensions—is anyone's guess. **DAVID HARRIS**



## ATLAS DETECTOR

**At 28,750 cubic meters**, ATLAS is the largest-volume particle detector ever constructed, and it was designed to do the widest range of experiments. When particles collide, four components record the result: the inner detector measures momentum; calorimeters measure energy; the muon spectrometer tracks muons (a collision byproduct); and the magnet system bends charged particles. Because the data rate is equivalent to 50 billion simultaneous phone calls, it also has systems to decide which data should be recorded or ignored.

1

### ACCELERATION

The collider occupies a nearly 17-mile circular tunnel. Two proton beams travel around the ring in opposite directions, racing through tubes kept at an ultrahigh vacuum and guided by superconducting magnets chilled to a temperature colder than that of outer space. Moving at near light speed, the protons make 11,245 circuits per second.

2

### COLLISION

The beams cross in four main detectors, where particles collide 800 million times per second. During the upcoming run, those collisions will produce an unprecedented 13 tera electron volts. That's 13 times the energy of a mosquito in motion, but squeezed into a space a trillion times smaller—a density similar to moments after the big bang.

3

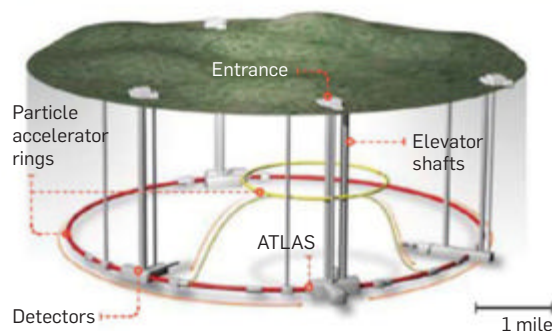
### CREATION

As Einstein theorized in  $E=mc^2$ , energy can be converted into mass (and vice versa). And so the energy of two protons colliding can combine and convert into massive new particles, including a top quark—the heaviest subatomic particle ever observed. Because they're unstable, these particles quickly decay into a number of new ones.

4

### DETECTION

As these secondary particles fly away from the collision point, the detectors measure their properties—including positions in space, energy, momentum, mass, and charge. Physicists use this information to deduce the identity of the particles created at the moment of collision and scour the data for anomalies that may indicate something entirely new.



1 mile



Flat-seamed baseball



Standard baseball

## FLAT-SEAMED BASEBALL

**For more than 100 years**, the baseball has remained more or less unchanged. This spring, college players will start their season with a new design. With seams that rise to only 0.031 inches, the ball shaves 0.017 inches off the standard seam height. Flatter seams make for a smaller wake and less drag, so a strong hit will send the new ball 20 feet farther than a standard one. For players, that means more home runs. For the NCAA, it means more exciting games and, hopefully, more spectators. **JUNNIE KWON**

# GLOBAL INTERNET

## Pervasive as the Internet

seems, less than half of the world's population has access to it, leaving some four billion people unconnected. This spring, engineers at Google's Project Loon will shift to the next phase in a grand plan to bring Internet to everyone. The goal: a network of high-altitude balloons (Loon is a play off the word) that will rain 4G LTE signals down to anyone with a 4G device. With it, farmers in remote areas will be able to access weather data; rural children will be able to pursue online educations; and Google will have four billion more eyeballs on its search engine. By year's end, Loon aims to have 100 balloons in the stratosphere, about 12.5 miles overhead. **NICK DAVIDSON**

1

### BALLOON

The balloon is a superpressure envelope—meaning it maintains constant pressure in changing temperatures—made from three-millimeter-thick sheets of polyethylene plastic. Partially inflated with helium for launch, it swells to full size once in the stratosphere. Twelve meters tall, 15 meters in diameter, and built to withstand  $-117^{\circ}\text{F}$  temps, it stays afloat for 100 days or more

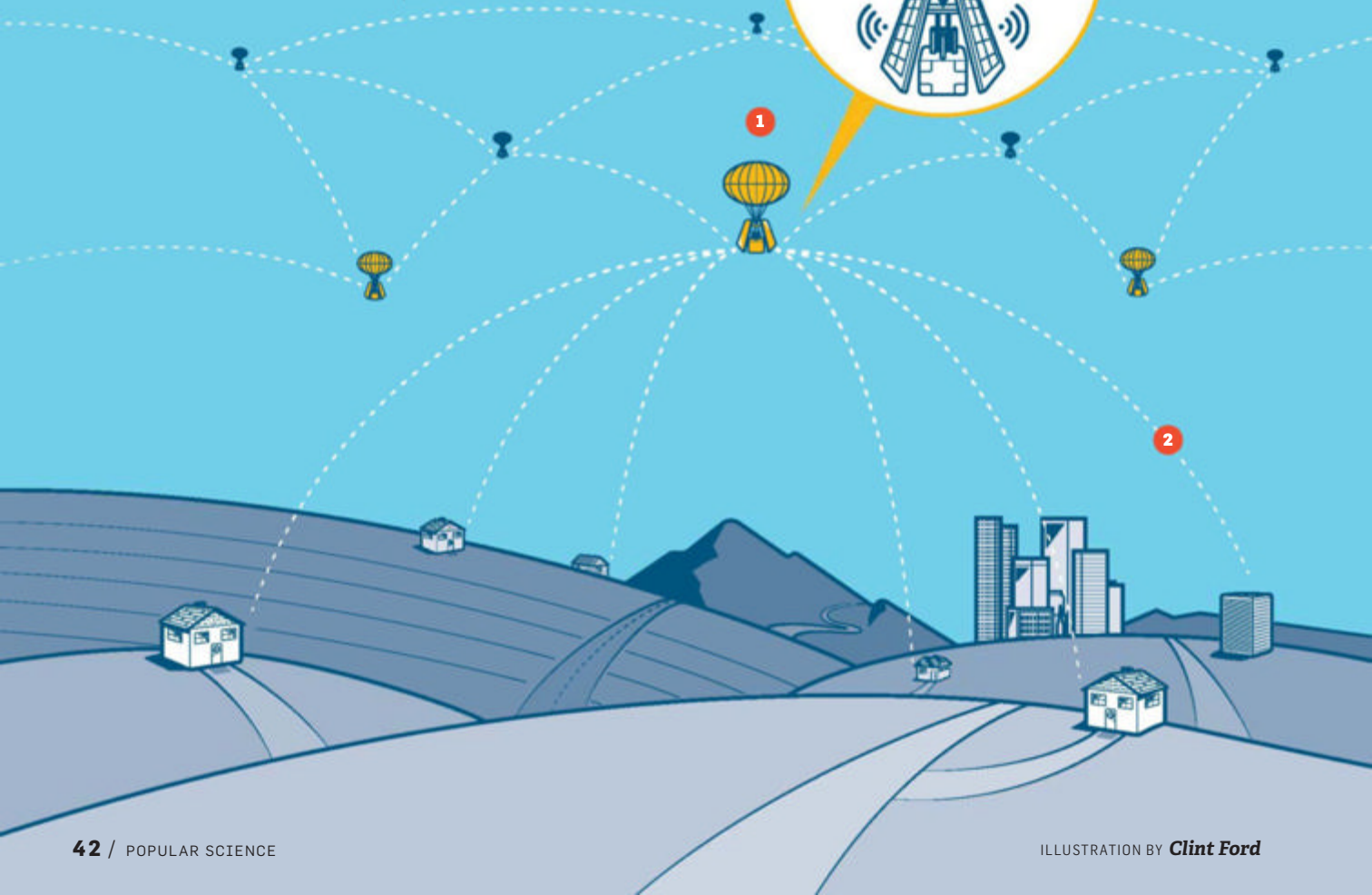
(about three laps around the globe) before engineers bring it down for maintenance.

Solar panels power the electronics (and charge a battery for night use). The electronics box holds a flight computer with navigational algorithms; an altitude-control system; a battery; and a handful of radios and antennas for receiving and relaying 4G LTE signals.

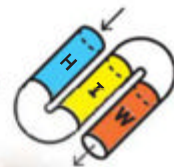


## NAVIGATING THE STRATOSPHERE

**Layers of stratospheric wind** move in varying, but predictable, directions. Ground engineers shift the balloon up or down through layers to steer it north, south, east, or west. To lower the balloon, they trigger an onboard pump to draw in air, which is seven times denser than helium. To raise it, they release air. Using algorithms based on National Oceanic and Atmospheric Administration wind-prediction data, they drive the balloon into the current that takes it where needed.







2

## NETWORK

Regional telecoms beam 4G LTE signals to the balloons. Each balloon communicates with dozens of others to form a mesh-like global network, always in motion. A single balloon relays the signal—like a cell tower in the sky—to a ground area many miles in diameter. Download speeds can reach up to 10 megabits per second—about the U.S. national average—to 4G devices. Google had tested the concept with Wi-Fi, but abandoned the plan because it would have meant building a network of ground-based antennas, too. With 4G LTE, people in even the most remote regions can access email and internet on a cell phone alone.

# CYBORG ROACH



**Disasters can bury survivors** in unstable rubble. Finding those victims may one day fall to small robots—but living insects enhanced with electronic parts could do the same job sooner. In 2012, researchers at North Carolina State University steered Madagascar hissing cockroaches by attaching electrodes to their antennae. Now, the scientists are developing tiny roach backpacks to pick up sound. “We’re trying to build a sensor network using insects,” says engineer Alper Bozkurt. “The aim is to detect calls for help.” The six-legged cyborgs will soon be tested at mock disaster sites. **RACHEL NUWER**

1

## BACKPACK

Researchers glue a 3-D-printed mount onto the insect’s body. This base connects the insect’s body to a second block that holds the electronic components—including a printed circuit board that acts as a microcontroller.

2

## CONNECTORS

Tiny electrodes inserted and glued into the antennae stimulate the neurons that guide motor function. By zapping those neurons, researchers can control the cyborg’s movements: Zap the right antenna and the bug goes left; zap the left and it goes right.

3

## RADIO

A two-way radio and a chip antenna communicate data about the environment, location, and nearby sounds. Computer algorithms can use this information to coordinate multiple cyborg roaches for search-and-rescue missions.

4

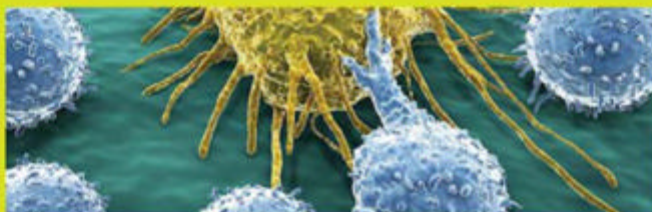
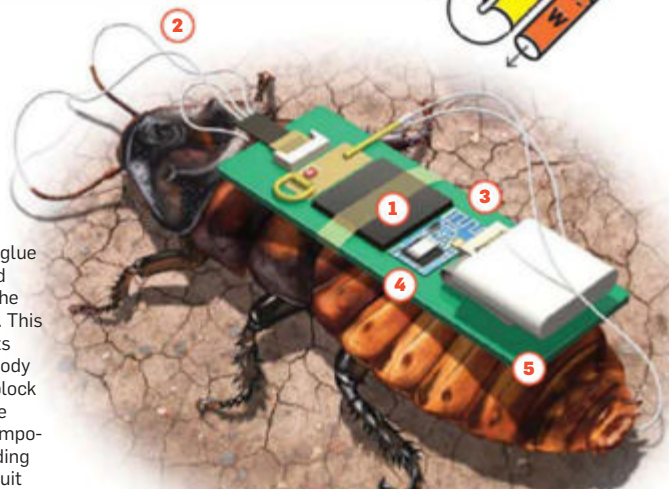
## MICROPHONE

Single or tri-directional microphones attached to the backpack capture sound and determine its direction. Algorithms analyze the sound to judge whether it likely came from humans. If so, the roach is deployed to investigate further.

5

## BATTERY

A three-volt lithium-polymer battery, weighing just half a gram, powers the backpack. It can be disconnected for recharging; alternatively, a small solar panel can fit over the backpack and refuel a drained battery in less than two hours.



# IMMUNOTHERAPY



**In the war against cancer**, doctors have discovered a powerful new tool: the immune system. The FDA recently fast-tracked approval of three new immunotherapy drugs, called PD-1 inhibitors, designed to help white blood cells hunt down and eradicate hard-to-fight tumors—indefinitely. “Chemotherapy almost always stops working,” says Jonathan Cheng, executive director of oncology clinical development at Merck. “The promise of immune therapy is that you’re training the immune system to attack something foreign, so you’re able to maintain that activity for a very long time—hopefully for the rest of a patient’s life.” **KATHARINE GAMMON**

1

## THE DEFENDERS

It’s the job of T cells to protect the body. When presented with bits of foreign protein from intruders, they activate and destroy infected cells.

2

## THE CHECKPOINT

To prevent an uncontrolled immune response, T cells carry a switch: a surface protein called the protein death 1 (PD-1) receptor. When engaged, it inhibits T cells’ proliferation.

3

## THE INHIBITORS

Tumor cells overexpress proteins called programmed death ligands that fit into PD-1 like keys to a lock, essentially turning T cells off.

4

## THE BLOCKERS

New drugs, such as Merck’s Keytruda, bind to PD-1 and block cancer cells’ access. The immune system unleashes additional T cells, which then find and attack tumors.

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# COUNTER



Guys with guns won't solve the scourge of the high seas. New technology could—if we'd just deploy it.



# PIRACY



By Erik Sofge



# TUCKED INTO A SLIP AT THE PORTSMOUTH NAVAL SHIPYARD, GHOST LOOKS MORE LIKE A SPACECRAFT THAN A SEABORNE COMBAT VESSEL.

As we approach in a small inflatable craft, I get a full view of the cabin—sharp and angular like a stealth fighter—looming over the dark water. The roof holds a mount for a machine gun and rocket launcher. Greg Sancoff, the founder of the New Hampshire start-up Juliet Marine Systems, asks the pilot to swing around to the stern. He points out two 12-foot struts, each of which connects to sleek pontoons. At full bore, he tells me, the pontoons ride just beneath the surface, while the cabin rises 20 feet above the waves. It is a case study in ominous, efficient engineering—a machine designed to fly through the ocean and invoke **fear**.

Sancoff tells me Ghost could serve many functions, including as a luxury speedboat or an attack ship for Navy SEALs. But the mission it appears best suited to is fighting pirates. With tremendous speed, and triple the range of any comparably sized vessel, Ghost is a natural interceptor. And because it rests on robotically stabilized pontoons, it remains steady in all but the roughest of seas. While attackers would struggle to aim weapons from a bucking, heaving boat, armed crew members on Ghost can engage with relative ease.

Although piracy doesn't concern most people, it is a constant threat for those who make their living on the ocean. Historically, the response has always been the same: guys with guns. That's effective, but it's a stopgap measure. When armed guards leave, pirates inevitably come back. Recently, a number of companies have set out to find a more permanent solution to the problem. Some have focused on detection, trying to ensure that ships never run

into pirates in the first place. Others have designed gear to ward off attackers at close range, including walls of grapple-resistant plastic and remote-detonated booby traps that spew irritant gas.

Juliet Marine's Ghost is perhaps the most daunting and far-sighted example of this trend. Stepping through the hatch in the Kittery, Maine, shipyard, it's clear the vehicle is just a prototype. The floor is a metal grate, and the walls are an open mass of cables and crudely labeled switches. There are only a handful of seats in the cabin, but there's room for more—up to 18, Sancoff says. That's more than a full squad of Marines, all of whom would arrive to an encounter fresh and ready to fight.

As I strap into a passenger seat, a thought occurs to me: Guns can combat piracy. But perhaps technology can end it.

**A**BOUT TEN YEARS AGO, Somalia fell into lawlessness. Decades of failed governments and drought had ravaged the country. Factions waged open warfare in the capital, Mogadishu, and the terrorist group Al-Shabab took control of much of the south. Few were concerned about securing the coastline. The conditions were ripe for piracy.

Typically, Somali pirates would set out on a mother ship. When they spotted a target (often tankers headed for the Suez Canal), they would launch one or more skiffs to intercept. Men armed with assault rifles and rocket-propelled grenades would ransom whole ships and crews. This crime wave peaked in 2011, when Somali

## The High Seas Arsenal

From the moment pirates appear on the horizon, there are multiple opportunities to stop them. Here's how technology can help fend off an assault at sea—or simply help a ship's crew survive it.

### LONG RANGE

As soon as a vessel appears on the horizon, **Matrix**, an early-detection system still looking for its first customer, uses rotating thermal cameras to identify it. People paid to monitor a feed of 12 images, which refreshes **constantly**, look for the telltale glow of a **boat's** engine or occupants. In clear conditions, potential attackers can be spotted up to 16 miles out.

Ships have reported using **Long Range Acoustic Devices** to deter pirates from as far as a mile away and as close as 250 yards. The concentrated acoustic energy can blast warnings in various languages—and so also redirect innocent **fishermen**—or simply hammer assailants at up to 153 decibels, potentially rupturing eardrums.

### MEDIUM RANGE

One of the best deterrents is also one of the most expensive—**armed guards**. Typical private security teams consist of three to four former military personnel with automatic weapons or hunting rifles. They can cost thousands of dollars per day but have a 100 percent success rate near Somalia. In West African waters, outgunned teams have been forced to surrender.

To protect crew members from incoming **fire**, key areas can be armored with quick-deploying **ballistic blinds**. These systems, which have been installed in limited numbers, drop into place and provide protection levels that range from stopping pistol rounds to absorbing damage from a rocket-propelled grenade.





Ghost rides along on buoyant foils, long propeller-tipped pontoons that sit six feet underwater.

pirates attacked 237 vessels. Then came the response: warships, private contractors, and drones. By the time Tom Hanks's *Captain Phillips* came out in 2013, the assault on the MV Maersk Alabama seemed like an epitaph for a bygone crisis. Last year, the number of reported attacks believed to have originated in the waters off Somalia dropped to seven, all of which were repelled by armed guards.

Though ostensibly a success, the counter-piracy effort in and around the Gulf of Aden merely reflects a deeply rooted historical cycle. The scourge of the high seas has existed since mankind learned to float. The Sumerians recorded incidents of piracy as far back as 3000 BC. Between the 16th and 19th centuries, Barbary pirates terrorized North Africa nearly unchecked. Much like urban crime, maritime violence is extremely hard to stop. When the pressure against it grows too great, it just shifts locations.

Last year might have been quiet off the coast of Somalia, for example, but activity was rampant in other places. According to the

**Much like urban crime, maritime violence is hard to stop. When pressure grows, it just shifts locations.**

International Maritime Bureau, armed gangs near West Africa stole supplies and personal possessions, siphoned fuel from tankers, and took a total of 144 crew members hostage. Kidnappings also occurred in Southeast Asia. Worldwide, it's believed that pirates are currently holding at least 30 crew members in captivity.

Even in the waters off Somalia, where private security teams protect most cargo ships, the threat of piracy lurks. Suspicious skiffs continue to stalk larger vessels, turning away only when it becomes clear that armed guards are aboard. According to Ian Millen, chief operating officer of Dryad Maritime, a shipping operations and risk intelligence firm in the U.K., four factors

GUIDO VITTI



#### SHORT RANGE

Desperate times call for desperate measures, such as trying to hit an incoming pirate vessel with high-pressure water from a fire hose or water cannon. Since targets are likely to fire back, the remote-controlled **Force 80 water cannon**, made by Unifire, can launch 1,321 gallons of water per minute at a range of 93 yards without exposing its operator to gunfire.



#### CLOSE RANGE

Once pirates get close enough to start throwing grappling hooks, a ship equipped with the **Possum system**—a series of external pods proposed as an add-on to the Matrix—can release a localized cloud of irritant gas to temporarily incapacitate the attackers, along with materials that obstruct the attacking vessel's propeller.



#### LAST RESORT

Boarding attempts can also be thwarted with the simple **Guardian system**. The plastic barriers bolt onto a ship's railings, and their bulbous shape and smooth surface sends grappling hooks skidding back into the sea. No one has made it over a Guardian-protected railing, including the Royal Marines during a two-hour test assault.

When all else fails, crews are often advised to retreat to a **Citadel**, the maritime equivalent of a panic room. Location and capabilities vary, but a best-case Citadel features bullet-resistant materials; food, water, and toilet access; communications; remote control of engines and steering; and a ventilation system to prevent attackers from smoking out the occupants.



Since Ghost is drive-by-wire and partially autonomous, Juliet Marine says it could be modified for unmanned operation.

currently contain the Somali piracy threat: the presence of warships, the presence of armed private security, commonsense practices like stowing ladders and properly installing razor wire, and communication with regional authorities. "But," he says, "if any one of those active ingredients disappears, you could see a reversal."

If history is any guide, one of those ingredients will fall away. Operating a handful of warships and aircraft near Somalia will cost the European Union \$8.3 million annually over the next two years. The average cost of an armed security team for commercial vessels is \$2,000 to \$4,000 per day. And there is no guarantee that the guns, guards, and warships will work. One of last year's deadliest attacks happened aboard a tanker in the Gulf of Guinea that was protected by private security. Guards killed two pirates before retreating to a safe room, but the assault continued, and one crew member died.

Governments and shipping companies could continue to fight pirates in the same reactive fashion they always have. What companies like Juliet Marine offer is a more proactive approach, one that could discourage pirates before they ever leave shore.

**DEALLY, SHIPS WOULD NEVER** require Ghost in the first place. That's the aim of Michael Scott, the founder of Matrix RSS, also in the U.K. The company is developing a 360-degree early-detection system that combines thermal imaging with human surveillance to maintain a constant watch. According to Scott, 68 percent of the reported attacks on vessels last year succeeded because of human error. "A human being on board a ship is the worst possible instrument you could choose for watching for pirates," he says. Crew members are easily distracted during 8- or 12-hour look-out shifts or may be absent from the deck or bridge entirely.

The Matrix system would turn the job of lookout into an out-sourced service. A pair of rotating cameras (one on either side of the vessel) would continually survey the surrounding ocean and beam a panoramic display of thermal images to manned terminals in locations like Vietnam and the Philippines. Human "sentinels" would watch the terminals at all times (and, in a somewhat dystopian twist, the terminals would watch the watchers and sound a warning tone if they disappeared from view). Using the system, sentinels could detect suspicious vessels up to 16 miles away and alert the crew by sounding the ship's alarms remotely. Scott claims this would give crews sufficient time to outrun or prepare to repel



**Don't let them get on the ship. Have something show up in the water that says, 'Get the hell out of here.'"**

intruders—at a cost, he projects, of as little as \$300 per day, or 15 percent of the rate of a typical armed team.

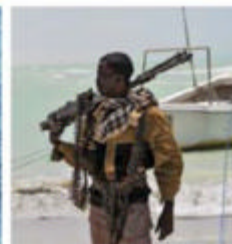
But say pirates do intercept an unguarded ship. For that, another U.K. start-up, Guardian Maritime, has developed an overhanging plastic barrier that bolts onto a vessel's railing and prevents assailants from gaining purchase. "No one's even come close to

beating it," spokesperson Jean Winfield says. When the initial design was completed, the company asked the Royal Marines to do their worst. Despite optimal conditions—a moored vessel in calm seas—the unit gave up after two hours. Even when simulating an inside job, where a line was thrown over the side, they couldn't make it past the overhang. "Add in the wobbly sea, the wind, and not having the right kit," Winfield says, "and we hope it's never going to be breached."

Matrix RSS, too, is developing a pirate-deterrent system, called the Possum. When pirates approach, the crew triggers pods that encircle the ship to release a cloud of irritant gas and materials to foul a skiff's propellers. Possum is designed to disable targets for up to an hour, enough time for a ship to speed away and for nearby authorities to engage the beleaguered assailants.

Engagement is where Ghost would come in. It would operate in troubled waters, using barges or other ships as its base, and respond to calls from distressed vessels. Two or three Ghosts in a region could take the place of dozens of armed guards and battleships. And because they'd be a constant force, they would not only defuse active threats but also discourage any new ones.

That's Greg Sancioff's vision, at least. The current prototype can reach only 30 knots (just 10 knots faster than a souped-up Somali skiff), although Juliet Marine says a production model will nearly double that speed. The secret, Sancioff says, is supercavitation, a process previously used only by torpedoes. The vessel's counter-rotating propeller screws, spun by 4,000-horsepower gas engines, and strategically positioned vents create a pocket of gas around each pontoon. "If you can put a blanket of gas around that hull," Sancioff says, referring to the pontoons, "you can reduce the friction by 900 times. We're basically boring two foam tunnels, five feet or six feet underwater, and we're flying through them." In addition to speed, supercavitation produces stability and fuel efficiency. Ghost can power through seven-foot waves with hardly a bump and its range is huge: about 800 miles.



French soldiers arrest pirates attempting to hijack a vessel in the Gulf of Aden in 2009. Right: A Somali man carries a high-caliber gun on a beach in Hobyo, a hub for pirates, in 2010.



# A Piracy Heat Map

**Despite** a continued decline in piracy near Somalia, commercial vessels are under assault in other parts of the world. There were 245 pirate attacks globally in 2014, according to the International Maritime Bureau. But the nonprofit believes many incidents go unreported in West Africa's Gulf of Guinea, where the real number of attacks could be 60 percent higher.

## NERD BOX:

Pirate attacks in 2014—both thwarted and successful—appear as circles centered either on a country or a hotspot in international waters, such as the Singapore straits.

## Number of attacks

- 1-2
- 3-8
- 9-24
- 25-100

## BIGGEST TARGETS

Product tanker

Bulk carrier

Chemical tanker

Crude-oil tanker

Container ship

Cargo ship

Gas tanker

Tug

Other

## Nigeria, April 29

Pirates boarded a Marshall Islands-flagged tanker and exchanged fire with onboard security. Two pirates and the chief engineer were killed.

## Somalia, January 17

After launching a skiff from a nearby mother ship, pirates fired at a Marshall Islands-flagged tanker. They gave up after armed security fired back.

## Malaysia, December 7

Seven pirates boarded a Vietnam-flagged tanker en route from Singapore, shot the third engineer in the head, and escaped with personal belongings.

In its discussions with Juliet Marine, the U.S. State Department has made clear its wish list for future counter-piracy systems. "The priority is: Don't let them get on the ship. Have something show up in the water that says, 'Get the hell out of here,'" Sancoff says. "Ghost is the only thing that has the range, speed, and chance of doing that."

**A**S FAR AS ONE CAN TELL, Sancoff is right. Nothing in the water, or in development, seems as well prepared as Ghost to both respond to and overcome a pirate attack. And yet, the ship's fate, like most counter-piracy technologies, has little to do with response times and success rates. Ultimately, the decision boils down to economics. Shipping is a massive business: More than 85,000 vessels move 17 billion tons of cargo per year. At that scale, nothing drives or dooms counter-piracy efforts quite like the dark calculus of who will pay for it.

Such questions have sunk counter-piracy efforts before. During the outbreak in Somalia, global defense and security company BAE Systems proposed two different technologies—an armed robotic boat called Protector that could patrol vulnerable waters and a nonlethal laser that would disorient and deter pirates at extreme ranges. There are no reports of either system being used to engage pirates, and the laser program vanished so completely that, when asked, BAE couldn't find records about the decision to ax it.

Of the recently developed technology, Guardian's plastic barrier is perhaps the best received so far. Since its launch in late 2013, the company has installed it on 209 vessels, including container ships and oil tankers, carrying \$55 billion worth of cargo. Juliet Marine has a steeper hill to climb—namely, it has to build a combat-ready vessel with the blessing but not the funding of the Pentagon. "Ghost is the first weapons platform developed solely by a private company in the United States since World War II," says Kevin Kinsella, the founder

## Juliet Marine argues that two Ghosts, at \$10 million apiece, could protect thousands of square miles.

of Avalon Ventures and a member of the Council on Foreign Relations. In the hands of a government-contracted defense firm, Kinsella believes that Ghost could have easily cost \$250 million to reach prototype stage. Instead, the start-up turned down a contract from DARPA—which would have forced it to share the rights to three core patents—and spent \$15 million. That includes \$5 million from Sancoff (who after founding Juliet Marine became wealthy

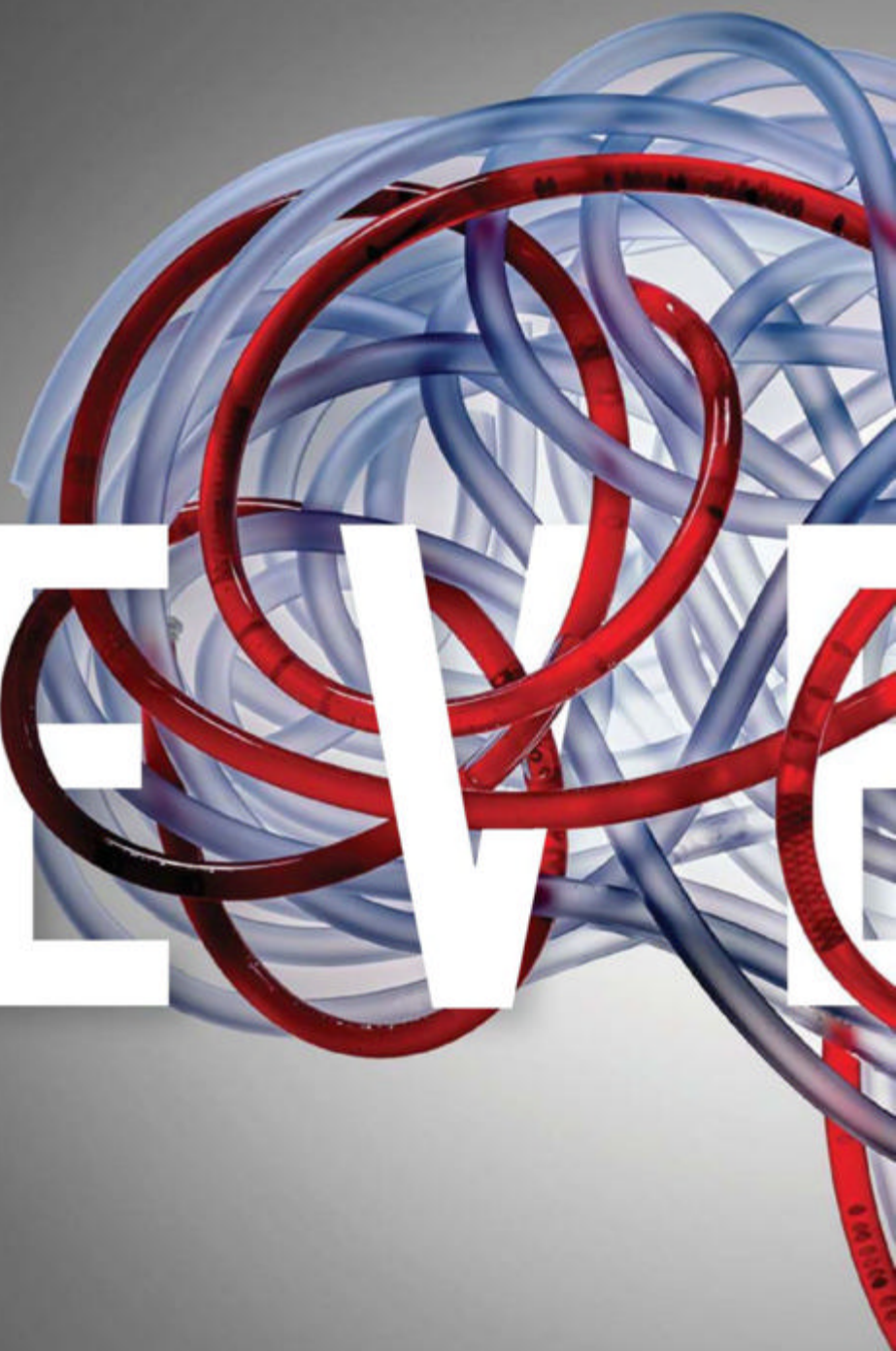
by starting and selling medical-device companies). "That's capital efficiency," says Kinsella, who joined Juliet's board of directors in 2012. "Ultimately, that will win the day in the defense community."

Juliet Marine argues that two Ghosts, at \$10 million apiece, could protect thousands of square miles. The U.S. Navy, while still in talks, has yet to bite. And although the prototype looks formidable, the company refused to test it for *Popular Science* against the fog, wind, and ice of a New England winter (after at least four cancellations, we never got further than the docked vessel). Sancoff now believes that his first customer will come from overseas—nations like Bahrain, Singapore, and the United Arab Emirates have expressed strong interest, he says. "You don't need to have a destroyer if you're Qatar or UAE or Saudi Arabia. What do you really care about? You care about making sure oil exports make it out of your country."

If you can do that in a new way, with fewer guys and fewer guns, you may change piracy forever. And while potential customers weigh the risks and rewards of proposals from Sancoff and others, the pirates won't be so patient. They'll be on the high seas, in one region or another, looking for their next target. 🚢

YES,  
YOU CAN

REVERSE



CERTAIN MALADIES MARCH FORWARD THROUGH TIME, GROWING PROGRESSIVELY

MORE DEVASTATING. NOW, SCIENTISTS CAN TURN BACK THE CLOCK.





What if a simple infusion  
could change everything?  
Scientists think young blood  
could reverse memory loss for  
Alzheimer's patients.

# ALZHEIMER DISEASE

STORY BY *Cassandra Willyard*

PHOTOGRAPHS BY *Sam Kaplan*

5,000,000

Number of Americans  
living with Alzheimer's  
disease

# Alzheimer's Disease

## BLINDNESS

### Stem cell therapy restores eyesight

### Young blood repairs memory

**MORE THAN FIVE MILLION** Americans are currently living with Alzheimer's disease, a number that's expected to nearly triple by 2050. Despite billions spent on research, the hunt for a cure has had little success. But new studies led by Tony Wyss-Coray, a neuroscientist at Stanford University, point to an unusual solution.

When Wyss-Coray began studying the blood of Alzheimer's patients, he noticed a marked difference from that of healthy individuals. Because the composition of

mice produced fewer new neurons and the old mice produced more. Next, the researchers injected old mice with young plasma, the fluid that remains when you strain the cells from blood. When tested in a maze, treated mice appeared to learn more easily and remember better.

The researchers are still trying to pinpoint what makes young blood so powerful. The plasma may contain proteins that quiet inflammation, a potential cause of Alzheimer's; identifying those proteins

**THE RESEARCHERS INJECTED OLD MICE WITH YOUNG PLASMA, AND THE MICE APPEARED TO LEARN MORE EASILY AND REMEMBER BETTER.**

blood changes with age, he wondered whether simply providing an infusion of young blood could impact the aging brain. To find out, he and his colleagues conducted a rather gruesome experiment: They stitched old and young mice together so that they shared a single circulatory system. Over the next five weeks, the young

may lead to new therapies. The team has launched a clinical trial to test the theory in humans: 18 patients will receive infusions of youthful plasma to see whether it improves Alzheimer's symptoms. It's a leap of faith, Wyss-Coray says, but one with few risks and tremendous potential.

**PEOPLE WITH AGE-RELATED** macular degeneration lose their vision slowly. Many never go totally blind, but objects blur, colors dim, and eventually faces can become unrecognizable. Last fall, Ocata Therapeutics announced a human embryonic stem cell therapy that could help restore disintegrating eyesight.

In the most common form of the disease, a thin layer of tissue, called the retinal pigment epithelium, begins to deteriorate. This tissue delivers nutrients and oxygen to the eye's rods and cones; without it those photoreceptors fail. Ocata coaxes embryonic stem cells to become retinal pigment epithelium cells, which can then be injected into the eyes. What happens next is still unclear: The cells may rejuvenate sickly rods and cones or generate new ones, says Eddy Anglade, chief medical officer for Ocata. Either way, people begin to see again.

Data from the company's first two clinical trials, published last year, confirm the treatment works. Ten of 18 people experienced some improvement in their vision, and the therapy seemed to halt the loss of vision in another seven. Some even had a dramatic recovery: A 75-year-old rancher who had gone blind in one eye was able to start riding his horses again. It's likely still a few years from Food and Drug Administration (FDA) approval, but Anglade hopes the treatment will one day become as common as cataract surgery.



# DIABETES

## New techniques shed weight and lower blood sugar

**MANY PEOPLE WITH DIABETES** control their illness with hefty doses of insulin and a smorgasbord of pills. For years, George Treff was one of them, but eventually, his body stopped responding. Even diet and exercise didn't help. "Whether I fasted or I sat down and ate 20 pounds of chocolates, nothing was really changing," he says. So in April 2009, Treff, who weighed 240 pounds at the time, tried something new: Roux-en-Y gastric bypass, a surgery typically reserved for morbidly obese patients.

The operation shrinks the stomach and reroutes the digestive tract. Postsurgery, patients eat less and absorb fewer nutrients, so they lose weight. Some people also show metabolic improvements in just a few days. In the wake of his surgery, Treff's blood sugar plummeted, and for a long time afterward, he didn't need to take insulin. Today, he takes just a fraction of the dose he once required. "These operations are better for treating diabetes than they are for treating obesity," says Carel Le Roux, a physician at the University College Dublin. New research may help explain why: The body increases production of bile acids, which bind to a receptor called FXR, prompting the release of hormones that help regulate blood sugar.

Scientists are now trying to use medication to the same effect. Michael Downes, a molecular biologist at the Salk Institute in La Jolla, California, published a study in January showing that a pill designed to activate FXR in the intestine helped mice shed weight and control their blood sugar. The pill could be even more effective than surgery. "You get all the metabolic benefits," Downes says—without the knife.

# HEART FAILURE

## Gene therapy keeps hearts pumping

**A FAILING HEART** leaves people tired, weak, and short of breath. Some ultimately need a transplant. But soon, there may be another option: gene therapy.

In order to beat, a heart's muscle cells must contract and relax. To contract, calcium ions flow out of the cells through a special organelle. To relax, a protein called SERCA2a pumps them back in. Failing hearts tend to have less of this protein than normal hearts, so Roger Hajjar, a cardiologist at Mount Sinai Hospital in New York, developed a way to deliver more. His lab

THE DEVICE MAY JAM THE SIGNAL FROM A HYPERACTIVE AMYGDALA AND EXTINGUISH THE FEAR PEOPLE WITH PTSD FEEL.

engineered a virus to carry extra copies of the gene that codes for SERCA2a into heart cells and insert them into the DNA. Consequently, the cells increase SERCA2a production. Although the protein can't undo existing damage, it can help the remaining cells work **harder**.

In 2007, researchers tested the therapy, called MYDICAR, in a clinical trial of 51 heart failure patients. Those who received the highest dose had fewer heart attacks and heart transplants. Three years later, they'd also experienced fewer heart-related hospitalizations and deaths. In 2012, the team launched a study of 250 patients. And last year, MYDICAR received a breakthrough-therapy designation from the FDA, which will accelerate the review process. Sian Harding, a researcher at Imperial College London and Hajjar's collaborator, is optimistic about its prospects: "The therapy could allow you to live out a normal life," she says.

# PTSD

## Brain stimulation counteracts depression

**THE WARS IN IRAQ** and Afghanistan took a toll on the more than two million American men and women who served in them. Studies suggest that roughly one in five veterans will experience posttraumatic stress disorder (PTSD). For some, the nightmares and anxiety—hallmarks of the illness—disappear on their own. But for others, no amount of counseling and medication seems to help. "PTSD is associated with a tremendous amount of suffering," says Ralph Koek, a psychiatrist at the VA Sepulveda Ambulatory Care

Center in Los Angeles.

That's why Koek and his colleagues recently launched the first human study to see whether deep brain stimulation could help veterans who have failed to respond to other PTSD treatments. The team plans to implant electrodes in each of the six participants' amygdala, the region of the brain that links events to emotions. "In PTSD, it seems that the amygdala is linking events to fear," says Jean-Philippe Langevin, a neurosurgeon at the VA Greater Los Angeles Healthcare System. Scientists think the device may jam the signal coming from a hyperactive amygdala and help to extinguish the excessive fear people with PTSD feel in response to everyday events. Animal research seems to support that: A 2012 study on rats found that deep brain stimulation reduced hypervigilance more effectively than antidepressants.

DARPA is working on similar research. In 2013, the agency launched a \$70-million, five-year program to develop a brain implant. The device will monitor specific neural circuits, with the same goal: "We're aiming to transform people's lives," Langevin says. 

# GREETINGS FROM THE







## WHERE (RADIO) SILENCE IS A VIRTUE

**The town of Green Bank**, West Virginia, sits at the heart of the National Radio Quiet Zone, where cellphones, Wi-Fi routers, and broadcast antennas are all but absent. For most, it is a throwback to a different era. But for an increasing number of new residents, it is a rare refuge from wireless technology. Welcome to the fringe of the electromagnetic age.

BY **Steve Featherstone**

ILLUSTRATION BY MAX TEMESCU



## The Quiet Zone



**ONE DAY IN 2003**, Diane Schou's hair started falling out. She got rashes and lingering headaches. Her doctor didn't know what was causing her symptoms, but Diane began to have her suspicions. She'd fallen ill around the same time a new cellphone tower went up near her Iowa farm. When she drove by the tower, her headaches worsened. So she and her husband, Bert, jumped in their Winnebago and fled. Diane didn't know what she was running from. All she knew was that she felt better the farther she got from that cell tower, and civilization in general.

Months after leaving Iowa, while stopped at a state park in North Carolina, a forest ranger told the Schous about a place called Green Bank, West Virginia. It was in the middle of something called the National Radio Quiet Zone. So the Schous went to Green Bank for a few days. It was a nice place, but they quickly moved on, like gypsies of the electromagnetic age,



The Green Bank Telescope is so sensitive that even a poorly insulated electric fence miles away can skew readings.

searching for somewhere insulated from the technology now synonymous with modern society. Along the way, Diane learned that her affliction had a name—electrohypersensitivity, or EHS—and that there were other electrosensitives like her. She also learned that most doctors don't believe her condition exists, at least outside of her mind.

According to the World Health Organization (WHO), EHS is not a medical diagnosis, but rather a vague set of symptoms with no apparent physiological basis. Even so, the condition—whatever its cause—appears to be widespread. Olle Johansson, an associate professor of neuroscience at the Karolinska Institute in Sweden, says the number of people who claim to have EHS varies by country, from 8 percent of the population in Germany to 35 percent, or about 11 million people, in the U.S.

"There are few epidemic diseases this large," Johansson says. "Nowadays, wherever you live, whatever you do, you're whole-body exposed, 24/7."

For Diane, the debate around EHS was academic. Her suffering was real, and no matter how far she ran—to an island in Nicaragua or a yurt in Lapland—she kept coming back to one place: Green Bank,

population 143. In 2007, after racking up 170,000 miles on their RV, Diane and Bert sold off half their farmland in Iowa and used the money to buy a house in Green Bank. Diane has lived there ever since.

Over the past several years, Diane's symptoms have faded. Her rashes disappeared. Her hair grew back. And while she says a stranger's cellphone will still send bolts of pain through her head, she's recovered to the point that she can use a computer again. But she can never return to the farm in Iowa. Green Bank is her home now, and that's given Diane a certain sense of purpose. As a conductor on the electrosensitive underground railroad, she has helped, by her estimate, dozens of technological refugees find shelter there. More are arriving every year, and they're finding that getting out of the radiation is the easy part. Fitting into a small town is a whole different story.

**GREEN BANK IS MORE** a hamlet than an actual town. There is a library, a post office, and a school, but mostly it consists of farms and houses scattered throughout a pastoral valley in the Allegheny Mountains, surrounded by steep, forested slopes.

Three years ago, Melissa Chalmers and



PHOTOGRAPHS BY STEVE FEATHERSTONE





Diane Schou is a leader of Green Bank's electrosensitive community. At home, she can use a computer, but only sparingly.



a woman I'll call Jane (at her request for privacy), met through Diane on an EHS Internet forum. Both women are airline pilots, and they had been looking for a retreat from the Wi-Fi and cellphones they so often contend with while traveling. Diane encouraged them to come to Green Bank for a trial visit.

On a cold November evening, I met Melissa and Jane at the Green Bank Cabins, a row of three log cabins located next to the Dollar General store. Billed as a rustic escape from "the fast pace of life," the one-room cabins were built in 1810 and have since been updated with electricity and plumbing. I rented the cabin next to Melissa and Jane's. We planned to explore Green Bank together, so I could see how they responded. Things were not going well. Even after switching off the cabin's circuit breakers and lighting candles, Jane said she felt itchy. Every 20 minutes, she got up to check her soaring blood pressure with a portable monitor. Melissa was uncomfortable too. She winced occasionally at the stray electromagnetic pulses that she said needled her skin.

"It doesn't just stop at your skin, like light would," she said. "It goes into your body. You start getting all fogged out."

Melissa pulled a digital gauss meter from her luggage. She began tracing the web of electrical wires stapled to their cabin's log walls, searching for errant sources of electromagnetic radiation (EMR). Then she scanned the air using a radio frequency (RF) meter that looked like a prop from the set of the old *Lost in Space* program. She found slightly higher readings in that cabin than mine, so I obliged when they asked me to switch. The next morning, I found Melissa holding her gauss meter beneath some power lines running behind my cabin. "I think I found the source," she grinned. "I told you there was something."

A little later, I grabbed breakfast at Henry's Quick Stop and drove two miles up the road to see the town's most notable landmark, the Green Bank Telescope

(GBT), the largest steerable radio telescope in the world. Up close, the GBT is a behemoth of white steel and aluminium scaffolding taller than the Statue of Liberty. Its 100-meter dish is visible from just about everywhere in the valley, and

"IT DOESN'T JUST STOP AT YOUR SKIN, LIKE LIGHT WOULD. IT GOES INTO YOUR BODY. YOU START GETTING ALL FOGGED OUT."

it's perhaps the only thing in town that's more finely tuned to electromagnetic fields than electrosensitives themselves.

The purpose of the GBT is to capture extremely weak radio signals emanating from the farthest reaches of space. In 1958, the federal government created the National Radio Quiet Zone to shield the GBT and the nearby Sugar Grove listening post (now run by the National Security Agency) from electromagnetic interference. As a result, cellphone, television, and radio transmissions—all of which rely on electromagnetic waves—are heavily restricted within its 13,000-square-mile area and banned in a 10-mile radius around the GBT. Residents are not entirely cut off. They can access TV and Internet with cable. But Green Bank is one of the few places in the world where electrosensitives can be certain that no one is going to erect a cell tower in their backyard or bolt a smart meter to their house.

Although it's in the heart of the Quiet Zone, Green Bank isn't completely free of EMR. After all, sunlight is a form of EMR, and electromagnetic fields ring the planet. The big difference between natural sources and man-made ones is their intensity. "Compared to natural levels, the exposure levels today are astronomical," Johansson says. "I would even say biblical—enormously high." For example, he says, if you were to take a cellphone and place it on the moon in standby mode, it would still

be the most powerful EMR source in the universe from the perspective of Earth.

Electrosensitives say they feel electromagnetic fields the same way the GBT detects radio signals from space—except it hurts. "I feel like I'm being cooked to death every time I get in the plane," Jane says.

As palpable as Jane's symptoms are to her—and as certain as she is that they're caused by EMR—scientific consensus disagrees. Almost universally, scientists hold that most EMR has no adverse health effects at the levels people typically encounter. And no study has ever definitively linked EHS symptoms to RF radiation, a type of electromagnetic radiation that originates from wireless devices, such as Wi-Fi routers, cellphones, base stations, or Bluetooth antennas. "Health agencies have repeatedly waded through the scientific literature," says Kenneth Foster, professor of bioengineering at the University of Pennsylvania, "and they don't see any clear evidence that there's a problem other than if you put a rat in a microwave oven, it's bad for the rat."

The only recognized health risk from RF radiation is the heating of tissue (as in the rat in the microwave). In 1996, the Federal Communications Commission adopted a safety standard for RF-emitting devices based on thermal heating. That's why even though the standard is set far below levels recognized to cause harm, wireless companies still recommend not carrying your







← The café at the Green Bank observatory is one of the few lunch spots in town.

phone around in your pocket or sleeping with one too close to your head.

According to Joel Moskowitz, the director of the Center for Family and Community Health at the University of California at Berkeley, the test for the thermal standard is outdated if not irrelevant. "It's not at all reflective of what the average user looks like today and not really of any user anywhere," he says. "It's not even the right measurement." Moskowitz believes that

health warnings," Moskowitz says.

Melissa and Jane certainly had no shortage of questions by their second day in Green Bank. Jane's blood pressure hadn't gone down, and Melissa still felt tingly sensations on her skin. Something was triggering their symptoms, but Melissa's equipment couldn't identify what it was. According to a survey of dozens of studies, the biggest challenge in diagnosing EHS is that those suffering

"HEALTH AGENCIES DON'T SEE ANY CLEAR EVIDENCE THAT THERE'S A PROBLEM OTHER THAN IF YOU PUT A RAT IN A MICROWAVE OVEN, IT'S BAD FOR THE RAT."

science hasn't caught up with the rapid proliferation of RF-emitting devices—from smartphones to smart meters—that have been spilling radiation into our homes, schools, and workplaces over the past two decades. Electrosensitives may be the proverbial canaries in the coal mine, he says. He cites a growing body of research that suggests RF exposure has many nonthermal biological effects, including damage to sperm cells and changes in brain chemistry. "There are a lot of unanswered questions, obviously, but we clearly have evidence for precautionary

from it often exhibit what's called the "nocebo effect," where even the expectation of exposure to EMR can cause physiological symptoms. During dinner at the cabin, Melissa switched on her RF meter and began walking around the room. The reading was 100 times lower than what she'd recorded in the basement of her home in Canada before a cellphone company put up towers nearby. Puzzled by this, Melissa and Jane tried to square their symptoms with the extremely low measurement.

"Maybe I'm reading it wrong," Melissa said, pressing the meter's buttons.

"They don't call it the National Radio Quiet Zone for nothing," I said.

"Maybe it really is that low," Melissa shrugged. "It's just that I've never seen it that low."

**LIKE DIANE SCHOU,** Jennifer Woods's journey as an electrosensitive began with upheaval. In 1997, she quit her job as an architect and left her family in Hawaii. She spent the next decade adrift, mostly living out of her car as she drove across the country seeking a cure for her chronic health problems. She tried conventional medicine and homeopathic treatments, but nothing worked. Three years ago, she heard about Green Bank at an alternative medicine conference; within 48 hours, she was parked in Diane's driveway. "I weighed 80 pounds at the time," Jennifer said. "I was at death's door."

She went to live in a one-room shack in a hollow with no electricity or running water. Within nine months, she'd put on 50 pounds. "I did no medical treatment," she said. "I didn't change my diet. The only thing I changed was I got out of the radiation. That's proof enough that [EMR] was causing my illness."

Jennifer now lives in a one-room cabin on a wooded ridge outside of town that she designed and built herself. Her second home is the Green Bank Public Library, a small building situated on a hill near the middle school. A plaque out front announces it as the 2003 Rural Library of the Year. With eight computers hard-wired to the Internet, the library provides many electrosensitives with their only connection to the outside world. There's also a kitchenette in the back where Jennifer keeps a few groceries, since she doesn't have a refrigerator in her cabin.

One morning, Jennifer made coffee and chatted with Arnie Stewart, a library volunteer whom she considers her guardian angel. "I've got big gossip," whispered Arnie. "Monique married Tom." The news came as a shock. Monique is an outspoken EHS activist recently arrived from Florida; Tom is a Green Bank local known for his





traditional views. Later that day, Jennifer relayed the news of Monique and Tom's nuptials to Diane Schou.

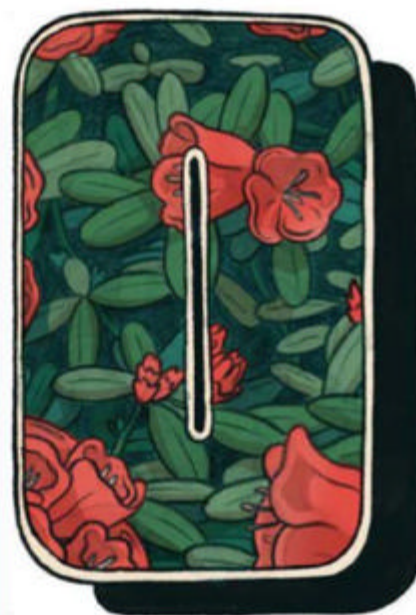
"It's not going to last," Diane frowned, "Tom doesn't believe in [EHS]."

Diane had reason to be doubtful. As the town's first electrosensitive resident and the unofficial representative for electrosensitives who came after her, she is a lightning rod for criticism. Four years ago, Bert Schou gave a lecture at Green Bank's senior center aimed at educating people about EHS. It was a watershed moment in relations between native Green Bank residents and the electrosensitive community. All the skeptics in town showed up, including Tom. After Bert's lecture, they accused Diane of everything from faking her illness to purposely delaying the construction of a local health clinic. "I was tarred and feathered," Diane said. "I regret that I was ever there."

"We crucified her," Arnie told me. "I'm sorry, but we did." The way he remembered it, a confrontation had been brewing for a long time. It began when Diane asked the senior center to replace fluorescent lights in one section so she'd have a place to eat. It escalated when she requested that someone bring a plate to her table so that she wouldn't be exposed to fluorescent lights near the kitchen. It

reached a climax when she asked for gluten-free options on the menu. By the time Bert gave his lecture, the burning issue on the minds of many in the audience wasn't the health effects of electromagnetic radiation—Arnie, for one, is convinced EHS is real—but rather Diane's constant demands for special treatment. "A woman with one arm stood up," Arnie recalled, "and she said, 'Look, Diane, no one brings my plate to my table.'"

Since then, relations between townsfolk and electrosensitives have reached a kind of détente. At Diane's request, the minister at her church no longer uses a wireless microphone. Her dentist switches off the fluorescent lights in his office. Cashiers at the Dollar General sometimes bring items outside and allow electrosensitives to pay for them in the parking lot. But Diane and other electrosensitives are alert to the tension lurking beneath social interactions. The situation isn't as simple as close-minded hillbillies reacting to overbearing outsiders. It's that in places like Green Bank, personal relationships go back generations. Anyone moving to a town of 143 would stand out, much less a dozen or so electrosensitives who show up and start turning out the lights. It's not hard to see how an "us versus them" mentality could take root.



ONE AFTERNOON, a group of us set out on a mission of mercy. A new member of the Green Bank EHS community was having a hard time with her home. Melissa, Jane, and Martin Weatherall, an electrosensitive and retired policeman from Stratford, Ontario, who has been coming to Green Bank since 2012, had offered to scan it for her. So we piled into a car and went. Along the way, we stopped in the town of Dunmore.

Five miles south of Green Bank, Dunmore consists of a few homes and a store situated at an intersection. The store was the sort of all-purpose gas station/bakery/de facto town hall often found in rural areas that haven't been colonized by fast food chains or retail behemoths. We ordered lunch and ate at a picnic table outside as logging trucks rumbled by. Everybody was in high spirits. Perhaps it was the warm sunshine or the low EMR levels. After swapping cabins with me, Melissa and Jane had been sleeping better. Jane's blood pressure was back down, and Melissa's chronic tinnitus was completely gone. "I feel good," Martin added, "definitely better than I do in Stratford."

Inside the store, I asked the proprietor, who had recently moved to the Quiet Zone, about her experience with electrosensitive customers. She launched into a

CONTINUED ON PAGE 78 →

→ Martin Weatherall tests an electric recliner for harmful radiation.





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Item 67455 shown

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**SAVE 50%**

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Item 46163 shown

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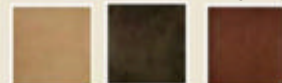
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## STATS

**Time** 6 hours

**Cost** \$129

**Difficulty**



## AN UMBRELLA STAND THAT OUTSMARTS THE RAIN

It's all too easy to forget an umbrella on a rainy day. But this is the 21st century—shouldn't your umbrella remind *you* when it's needed? Well, yes, it should. And it can do that via a stand that lights up when the forecast calls for rain.

There are several ways to make a smart umbrella stand, but the easiest uses littleBits modules, miniature circuit boards that snap together with magnets. The stand communicates with an online weather forecast through the Internet-connected cloudBit module and a service called IFTTT (short for "If This Then That"), which helps Web applications talk to one another. For example, if Yahoo Weather predicts rain, then

IFTTT will send a command to the cloudBit, telling the electroluminescent wire on the stand to illuminate.

Although you could just wrap the littleBits light wire around a prefabricated umbrella stand, it's more fun to customize a 3-D-printed version. To take the project one step further, modify the open-source designs. Try adding a littleBits pressure sensor to the stand so it can detect an umbrella's presence and ping your phone if you leave the house unprepared.

JEREMY BLUM

# 39

Average feet of rain per year in Mawsynram, India, the rainiest place in the world

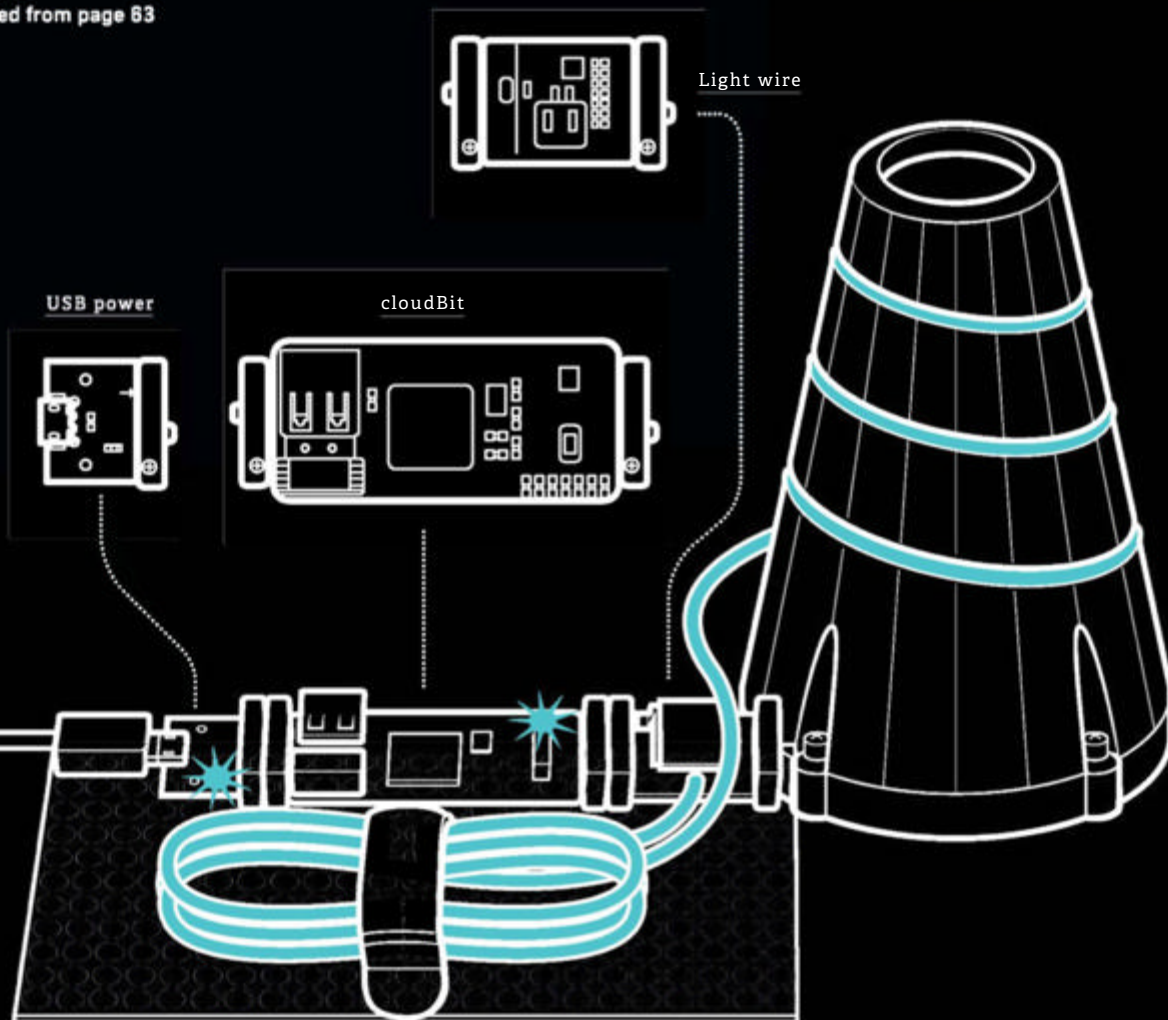
For links to advanced instructions, design files, and more, visit [popsci.com/smartumbrella](http://popsci.com/smartumbrella).



continued on page 64

# Build It

continued from page 63



## MATERIALS

- 3-D printer filament (PLA works well)
- 4 M3 hex nuts
- ¼-inch-thick, 3-inch-diameter stainless steel plate
- 4 10mm M3 hex bolts
- Optional: umbrella stand
- Optional: Tape or zip ties
- Mounting board
- littleBits modules: USB power, cloudBit, and light wire

## TOOLS



3-D printer



Wire cutters



Allen wrench for M3 bolts



Wi-Fi network

## INSTRUCTIONS

**1** If you have an umbrella stand, skip to step 3. Otherwise, download and print the 3-D design files for the two parts of the stand.

**2** On the top part, use wire cutters to clip the support structures off the spiral. This will help you install the light wire. On the base part, pressure-fit the nuts and insert the steel plate. The plate's weight will keep the stand steady

when holding large umbrellas. Bolt the base to the top, and pop the light wire into the spiral.

**3** On a premade stand, just wrap the wire around it and fasten with tape or zip ties.

**4** Snap the littleBits modules onto the mounting board, with USB power feeding into the cloudBit and then the light wire.

**5** Follow the instructions

that came with the cloudBit to connect it to Wi-Fi and register it.

**6** Create an account at *IFTTT.com*. Add the littleBits channel and make sure your cloudBit shows up.

**7** Create a new "recipe" on IFTTT. For "This," select the "Weather" channel. Pick "Current Condition Changes To" and select "Rain" to activate

the recipe under rainy conditions.

**8** For "That," select the "littleBits" channel. Pick "Set Output Level" for the option. Choose your cloudBit, and set the level to 100 and the duration to "Forever."

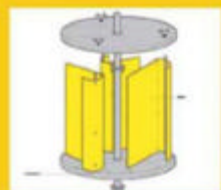
**9** Repeat steps 7 and 8, but choose "Clear" for the weather condition and zero for the output level. This tells the light wire to turn off on clear days.



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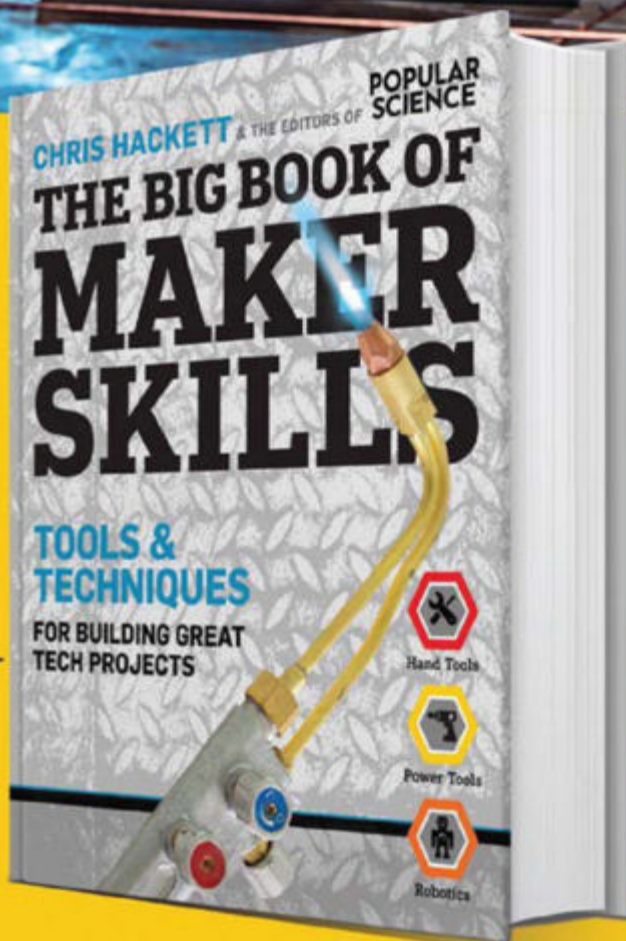


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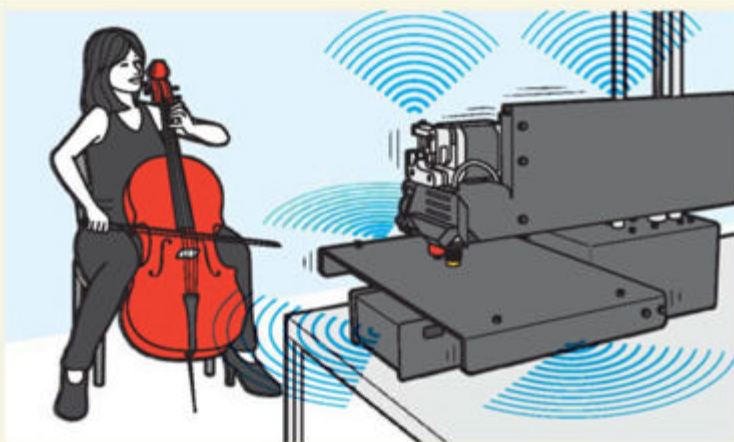
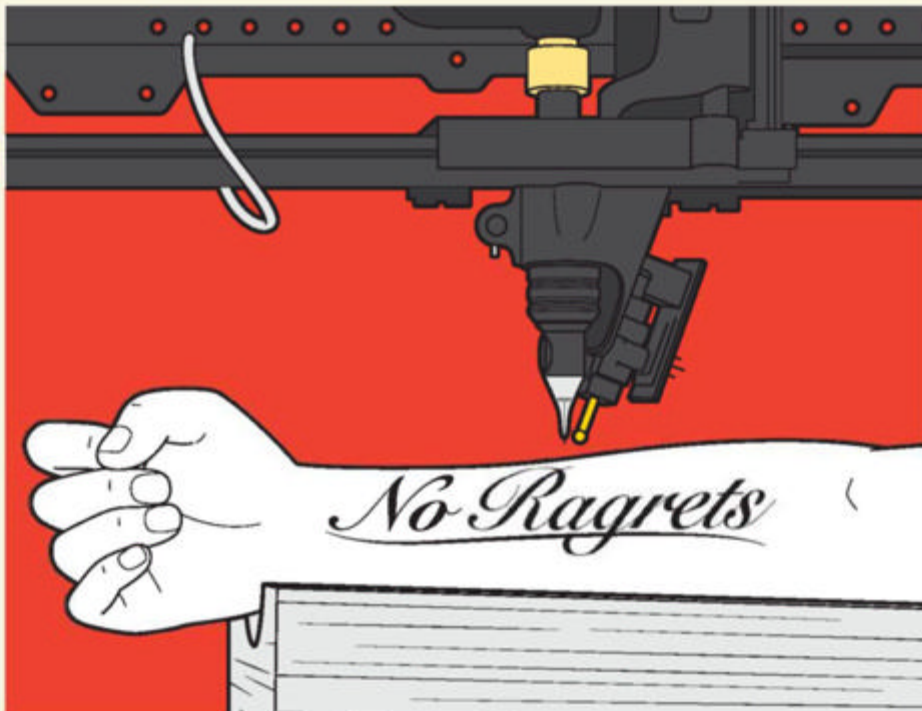
# Bet You Didn't Know a Printer Could ...

## 1 TATTOO SKIN

Eighteen months ago, design students Pierre Emm, Piotr Widelka, and Johan da Silveira decided to turn a MakerBot 3-D printer into an automated tattoo artist. They replaced the printer's extruder with a tattoo gun and added a haptic sensor to detect variations in the skin's surface. To translate tattoo flash art into digital files, they modified the Autodesk design software that is often used with 3-D printers. Guided by computer-aided design, the printer successfully inked a circle—which the designers consider the perfect shape to test precision—onto a human arm in October 2013. Their company, Appropriate Audiences, plans to bring a consumer version of the machine, called the Tatoué, to market in 2016.

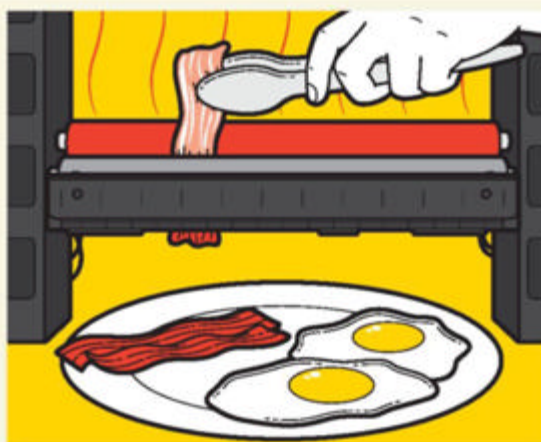


**Printing on paper** is so last millennium. To give inkjet and 3-D printers new purpose, makers swap out components like extruders and motors, program them with modified code, or both. The hacked machines can do just about anything. **CORINNE IOZZIO**



## 2 PLAY SONGS

When Silviu Stroe began to tinker with his Printbot Simple 3-D printer, he noticed something interesting: The spinning of the stepper motors, which move the nozzle through the print area, sounded like musical notes. As the speed varied, the tone changed. That meant the printer was capable of playing tunes. By assigning a particular speed and duration to each note, Stroe converted a MIDI file of the *Star Wars* Imperial March into G-code, the software language printers understand. According to Stroe, the printer's tonal range is virtually unlimited, so it should be able to belt out Barry White one moment and Beyoncé the next.



## 3 COOK BACON

During last year's Deconstruction 48-hour hackathon, Team Rabbit Hole decided to make breakfast for dinner. As team members ate their meal, they also chewed over an idea: using a laser jet printer to automate the bacon-cooking process. The printer's fuser roller heats up to 450°F to melt toner powder onto paper. To control speed, the hackers replaced the motor with an electric screwdriver. Then they fed bacon over the roller, cooking the strips to crispy perfection in a few passes.



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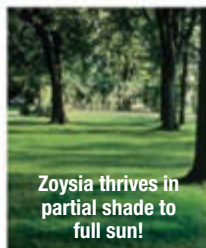
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Zoysia thrives in partial shade to full sun!

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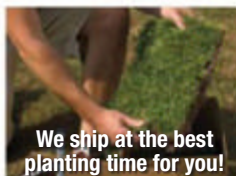
No more pulling out weeds by hand or weeds sprouting up all over your lawn. Zoysia Plugs spread into a dense, plush, deep-rooted, established lawn that drives out unwanted growth and stops crab-grass and summer weeds from germinating.

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When ordinary lawns brown up in summer heat and drought, your Zoysia lawn stays green and beautiful. The hotter it gets, the better it grows. *Zoysia thrives in blistering heat (120°)*, yet it won't winter-kill to 30° below zero. It only goes off its green color after killing frosts, but color returns with consistent spring warmth. Zoysia is the perfect choice for water restrictions and drought areas!

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# TEACH A FISH TO WALK



A Senegal bichir raised on land walks better: It slips less, lifts its head higher, and places its fins closer to its body.

## STATS

**Time** 8 months

**Cost** \$70

**Difficulty**



**Four hundred** million years ago, our ancestors crawled out of the sea. Last year, biologist Emily Standen imitated the ancient feat by raising pet store fish on land. A species called the Senegal bichir can breathe moist air through a primitive lung and scramble around on its front fins. After raising juvenile fish out of water for eight months, Standen's experiment revealed that the bones supporting the bichirs' fins had changed shape to make walking easier. In our fishy forebears, similar adaptations may have paved the way for genetic changes. Find out for yourself—create a living fossil in your living room. **SHANNON PALUS**

## MATERIALS

- Medium-size acrylic aquarium
- Sand and gravel
- Water
- Airline tubing and control kit
- Bucket
- Hot glue gun
- Aquarium pump and filter
- Safety pin
- Senegal bichir

## INSTRUCTIONS

**1** Drill a small hole in one wall of the aquarium, about an inch from the bottom. Line the tank with an inch of sand and gravel; add water until there is a layer about  $\frac{1}{16}$  of an inch thick on the bottom of the tank.

**2** For drainage, thread airline tubing through the hole until one end reaches the water inside, and place the other end in a bucket below the aquarium. To secure the tubing and prevent leaks, seal the hole's edges with hot glue.

**3** Fill the bucket with water and clip the filter to the side. Take a T-junction from the

kit, connect a valve to the perpendicular part of the T, and hook airline tubes onto both arms.

**4** Connect the tube on one arm to the pump, and string the other arm's tube across the top of the tank. Use a pin to poke holes in the tank's tubing so water will come out in a fine mist.

**5** Drop the T-junction in the bucket. Optionally, add plants to the tank to spruce up the environment. Then introduce the young Senegal bichir to its new home.



## Tech Support

**Q:** How can I make conductive paint into a liquid switch that turns a lightbulb on and off?

—PATRICK STEVENSON-KEATING

**A:** You'll need to suspend the water-soluble conductive paint in a liquid it can't mix with: an oil with low viscosity. We recommend clear baby oil. Put the paint and oil in a hollow glass base below the lightbulb. You can turn on the lamp by tilting the base until the blob of electric paint makes contact with two electrodes extending from the bulb. To turn off the light, simply rotate or tilt the lamp until the paint is no longer bridging the gap between the electrodes.

—PETER KRIGE, BARE CONDUCTIVE  
AS TOLD TO ALISSA ZHU



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# From Nuclear Missileer to Plant Engineer



From 2005 to 2008, Keira Havens could have started World War III just by turning a key. As a missileer in the United States Air Force 90th Missile Wing, she manned a console that was linked to a battery of nuclear weapons and sealed behind an eight-ton steel door in a concrete bunker 60 feet beneath a missile field.

But Havens's true interests lay outside the military, with its rigid checklists and strict protocols. By the end of three years, Havens, who has a degree in molecular biology, was ready for a change. "I was interested in doing something on my own," she says, "answering new questions instead of just reciting things that I had learned." She joined a University of Colorado biotechnology lab that was genetically engineering plants to change color in the presence of explosives. "One goal was to replace

the TSA in airports with a jungle of living sensors," Havens says.

After this experience, Havens struck out on her own, founding biotech company Revolution Bio-engineering last year. With Dutch colleagues, Havens began work on a color-changing petunia, which turns from red to white when watered with a chemical trigger. Eventually, she plans to engineer blossoms that change color throughout the day—hot pink in the morning, deep purple in the afternoon. **DANIEL GRUSHKIN**

NIKOLAI BRAUN



✓Yes



✓Yes



xNo



✓Yes



✓Yes



✓Yes



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## Hackertainment

A Hobbit Sword That  
Detects Free Wi-Fi

5,800,000 | Estimated number of global  
public Wi-Fi hotspots in 2015



In *The Hobbit*, the sword Sting glows blue whenever Bilbo Baggins approaches orcs or goblins—a convenient feature in Middle-earth. In the real world, free wireless detection is more useful. “We’re always looking for fun projects that get people excited about DIY culture,” says Zach Supalla, whose company, Spark IO, produces hardware for making Internet-connected devices. So Supalla and his co-workers used the Spark Core, their Wi-Fi development kit, to hack a light-up toy Sting. Now it glows in the presence of unsecured Wi-Fi networks, not enemies. **ROSE CONRY**

## HOW TO MAKE STING SMARTER

## SEPARATE

The Spark IO team unscrewed the toy sword's hilt to expose the electronics: the LEDs that make the blade glow, a vibration switch that detects motion, and the sound system responsible for battle noises.

## SOLDER

Team members cut these wires and soldered them to the pins of the Spark Core board. Then they programmed the board with code that scans for unsecured networks and controls the lights and sound.

## SLASH

The reassembled sword lights up when it detects unsecured Wi-Fi. Swinging the weapon produces clangs and swooshing noises and prompts it to publish a message on the network announcing it's vanquished another foe.

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# New electronic lure may catch too many fish; one state bans it.

A bass every seven minutes.

by Mike Butler

**NEWARK, DE**—A new fishing technology that set a record for catching bass in Mexico is now showing its stuff in the U.S. It has out-fished shrimp bait in Washington State and beat top-selling U.S. lures three to one in Florida. The new technology is so effective one state, Wyoming, has banned its use.

The breakthrough is a tiny, battery-powered electrical system that flashes a blood-red light down a lure's tail when its moved in water. Fish think it's an injured prey and strike. Some fishing authorities, like those in Wyoming, think that gives fishermen too much of an advantage.

They may be right. Three fishermen using a flashing lure in Mexico caught 650 large-mouth bass in just 25 hours. That's a bass every seven minutes for each person, and a record for the lake they were fishing. They said the bass struck with such ferocity they hardly lost a strike.

In Florida two professionals fished for four hours from the same boat. One used a flashing-red lure; the other used some top-selling U. S. lures. The new, "bleeding" lure caught three times as many fish.

Before reporting this, I asked a veteran fisherman in my office for his opinion. Monday morning he charged into my office yelling "I caught six monster fish in an hour with this thing! Where did you get it?"

Then I phoned an ichthyologist (fish expert).

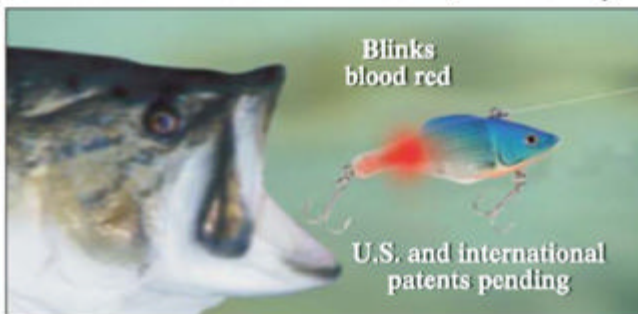
"Predators - lions, sharks," he said, "will always go for the most vulnerable prey. Fish are predators, so if a fish sees a smaller fish bleeding, it knows it's weakened and will strike."

"If a lure could appear to be a live, bleeding fish, a few fishermen could probably empty a lake with it."

I told him three almost did.

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GO AHEAD...

# Ask Us Anything

ANSWERS BY **Daniel Engber** / ILLUSTRATIONS BY **Jason Schneider**

## Q: WHY DON'T ELECTRIC EELS ELECTROCUTE THEMSELVES?

**Short answer** It's complicated.

**A:**

The electric eel is a variety of freshwater fish with specialized organs that discharge electricity. Many species use these jolts to sense their surroundings or communicate (as in courtship). A few species, including electric eels, electric rays, and electric catfish, can emit enough juice to stun other fish, yet they never seem to shock themselves.

Body size may be key: An electric eel can grow to eight feet long and weigh as much as 50 pounds, making it orders of magnitude bigger than its victims. The charge it delivers—up to 650 volts—would cause much less damage to the eel itself.

Out of water, however, an electric fish may be more susceptible to its own power. Jason Gallant, a zoologist at Michigan State University, has heard that electric eels spasm when pulled from the water. That's probably because their charge doesn't readily dissipate through air. Instead, it travels across the fish's wet skin, delivering a more concentrated shock. Also, Gallant's team found that several groups of electric fish express the same genes, which encode structural proteins that could insulate their electric organs.

These are all just speculations, though. In truth, no one really knows why electric eels don't shock themselves. Vanderbilt neuroscientist and electric eel expert Ken Catania

calls the fish "optimized biological Tasers—and I'm not just trying to spin it so it sounds cool." But he says their ability to zap a foe without getting zapped remains a mystery.



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## Q: HOW COMMON IS SCIENTIFIC FRAUD?

A:

**The troubling truth** is that scientists who lie to their peers are rarely exposed. A February investigation revealed that most scientific fraud uncovered by inspectors for the Food and Drug Administration never gets identified as such in the academic literature. Similarly, in the PubMed database of biomedical research, only one in 10,000 recent papers, or 0.01 percent, has been retracted (most often for fraudulence).

Other measures of misconduct, however, hint at much higher rates. Daniele Fanelli, a senior research scientist at Stanford University, pooled data from 18 surveys and found that almost 2 percent of scientists admitted to fabricating or falsifying their work or manipulating data. When asked whether they'd ever seen misconduct among peers, 14 percent said they had. Fanelli then compared survey answers between decades to spot changes in how these shenanigans come to light. "Scientists have become less likely to admit misconduct," he says, "but they're

**Short answer** At least one in 50 scientists is doing something fishy.

no less likely to report the misbehavior of their colleagues."

Fraudsters today may be cagier for fear of getting caught, or perhaps misconduct itself has become subtler and harder to assess. To gauge this softer form of fraud, Fanelli examined bias in the scientific literature. Published data is now more likely than ever to show positive results that support a scientist's hypothesis, he says. Researchers may toss out data points that don't seem right or run experiments many times and publish only the best results. Such gentle coaxing in the lab may even be unconscious.

Whatever is driving the trend, interesting patterns emerge. Fanelli found that bias varies between fields: Psychology and psychiatry are most afflicted, while astrophysics shows very little bias. Papers out of U.S. labs tend to give stronger or more positive results than the same research queries in Europe or Canada, perhaps due to greater competition or pressure to publish. Growing awareness of misconduct might have made rogue scientists savvier. "They now know where to stop before what they do is considered intentional fraud," Fanelli says. 

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## The Quiet Zone

→ continued from page 59

diatribe about "outsiders" who annoyed her with their petty demands and condescending attitudes and unwillingness to fit in. I thanked her and left, but she waved me down in the parking lot. Back in the store, a knot of grim-faced men confronted me. The proprietor loudly proclaimed that with the sheriff's deputy as her witness, she was retracting everything she'd said. Unless a camouflage T-shirt qualified as a uniform, none of the men appeared to be officers of the law. One man took my tape recorder and barked at me to come outside with him. As I explained the situation, his eyes narrowed each time I used words like *electromagnetic* and *journalist*. Finally, he returned my tape recorder, pointed his finger at my chest, and growled, "Just be careful what you're doing here."

**OVER SIX DAYS**, Diane gave Melissa and Jane the full Green Bank experience. They visited the post office and library, toured

the observatory and the town dump. They attended a mountain music jamboree headlined by a band whose fiddler was also the GBT's principal scientist. On Sunday, Diane shepherded the women to two church services 15 miles apart. They were welcomed just about everywhere. After the service at the Church of the Nazarene in Durbin, the organist asked Jane what it felt like to have EHS. She listened intently to Jane's reply and posed a question that electrosensitives have been asking for years. "They make allotments for all kinds of ailments," the organist said. "Why can't they recognize this one?"

Jane didn't have an answer—because there isn't one. Without an official medical diagnosis, it's difficult for EHS sufferers to claim benefits from insurance companies and government health agencies. Only Sweden recognizes EHS as a functional impairment, equivalent to a disability. But activists are beginning to have an impact on attitudes toward EHS and EMR-related issues, such as the use of

wireless networks in public schools. Some day they hope that the medical establishment will treat EHS like other mysterious syndromes, such as fibromyalgia. They won a moral victory in 2011, when the WHO classified RF radiation as "possibly carcinogenic" in response to its Interphone study, which found a 40 percent greater risk for certain brain tumors at the highest exposure levels. (Scientists, however, did not find an increased incidence in cellphone users overall.) Then, in February of this year, France restricted the use of RF devices in daycare centers, citing a precautionary approach to exposure. Those gains aside, few if any studies are taking seriously the issue of EHS, and the inexorable expansion of wireless technologies does not appear to be slowing. Barring a breakdown in relations between electrosensitives and townsfolk or defunding of the GBT, Green Bank will continue to attract technological refugees searching for a safe haven from the electrosmog they feel is smothering the rest of the world.

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Near the end of Melissa and Jane's visit, Diane hosted a potluck dinner for them at her house, a large brick colonial on a wooded hill overlooking a bend on a dark country road. Electrosensitives showed up with bottles of wine and covered dishes. Faces lit by flickering candlelight, they gathered around Diane's kitchen table and

suddenly struck low by an overdose of EMR and are now struggling with health problems. Electrosensitives fervently believe that it's just a matter of time before the rest of the world catches on to what they already know.

"Your body is getting affected—it's just going to take a few years to really know it,"

"Well they should be nervous," Diane said. "They could be harmed too."

"EMF people," Jennifer offered.

"Electrocuted people," Martin deadpanned, and everybody laughed.

Although the conspiratorial tone got a little thick at times, the electrosensitives sitting around Diane's kitchen table weren't technophobic Luddites or doomsday preppers nursing violent fantasies of social collapse. Their conversation seemed quaint in its directness, an artifact from a time when communication between people was unmediated by texts, tweets, and Facebook updates thumbed on smartphones. Over dessert, Jane announced that she was getting a realtor to look for houses in Green Bank. As for Melissa, she didn't even want to go home. "I feel like I can finally have my life back," she said.

**DESPITE ITS ABUNDANT** natural beauty and rural charm, electrosensitives come to Green Bank because they have no other place to go. Unless you know some-

ELECTROSENSITIVES FERVENTLY BELIEVE THAT IT'S JUST A MATTER OF TIME BEFORE THE REST OF THE WORLD CATCHES ON TO WHAT THEY ALREADY KNOW.

talked long into the night about the usual topics: rumors of a Wi-Fi network that the observatory was installing for town residents, old Soviet studies on microwave radiation, and the looming wireless pandemic. Everyone contributed a cautionary tale about "normal" people they knew—a friend, a neighbor, a co-worker—who were

Martin warned me, "unless you end up like us, and then you'll wish you'd never seen wireless stuff."

I asked the group what they preferred to be called—electrosensitives? EHSers?

"I prefer injured or harmed," Diane said.

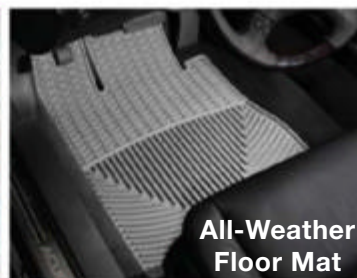
"That gets people very nervous," another person said.

CONTINUED ON PAGE 80 →



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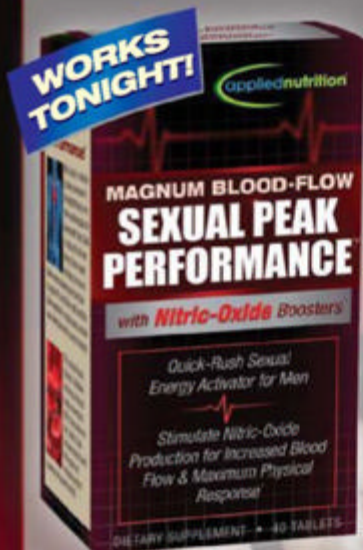
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APRIL 2015

## The Quiet Zone

continued from page 79

body, it's almost impossible to find a job or a place to live there. Some electrosensitives leave town soon after they arrive, unable to cope with the remoteness of the place. But Diane Schou has plans to make Green Bank more accessible. Through a nonprofit, she bought 14 acres of land to establish an electrosensitive retreat. Money for the property came from private donations. On my last morning in Green Bank, she took me to see the land. I followed her car down a narrow dirt lane set between double-wide homes. We came to a clearing scented by wood smoke and pine needles. A small cabin stood at the edge of the clearing.

"If people find that they're affected by [EMR], they can get away from it, get it turned off, recover," Diane said. That's how it worked for her. Living in the Quiet Zone, away from the cell towers, has allowed Diane to recuperate. Now, she can tolerate limited excursions into the wireless world to visit her son in Baltimore. "You might be able to go back home and take cautions and be able to live maybe a normal life," she said, pausing. "Maybe. Cautiously."

Diane walked around the clearing, gesturing to places where she planned to build structures. Cabins over here. A communal area over there. In this spot, a shielded computer room. Other board members of the nonprofit vetoed the computer room. Too much EMR, they said. But Diane insisted. People have lives. They might want to keep working or email or Skype with their families. It's a community, not a cult.

"That's why I call [EHS] technological leprosy," Diane said. "We can't be with other people in society. We have to live like lepers. Technology is wonderful stuff—if we aren't harmed by it."

Leaving town, the GBT's big white dish floated in my rearview mirror like a harvest moon shining in the clear autumn sky. At an intersection somewhere in the mountains, I realized that I'd left my road map at the cabin. My cellphone didn't work, and the radio played only static. I couldn't remember the last time I'd gotten lost, but I knew I'd left the Quiet Zone when I heard a preacher's voice cutting through the static on the radio. "You see, our problem is not our weaknesses," he bellowed. "Our problem is not staying plugged in! We need to plug into our power source, which is God!"

I turned the radio off, relishing the silence while it lasted. ❧

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## From the Archives

# When Insects Work for Us



**"No movement** of the insects is left unobserved," wrote *Popular Science* in May 1924. Indeed, to gather data that might help commercial beekeepers, government researchers trained their eyes and a number of sensors on hives of 3,750,000 honeybees. With anemometers, barometers, hydrometers, and thermometers they monitored the bees' response to changing weather conditions. Magnifying glasses on the hives gave researchers a safe view of life inside. "Woe betide the unfortunate investigator—human or otherwise—who would personally invade the privacy of the bees' home!" we wrote. Now, scientists are outfitting insects with sensors to probe our environment. For example, cockroaches carrying a microphone and a microcontroller will be sent into disaster sites to detect survivors. To learn about how they work, turn to page 43. **JUNNIE KWON**

10

Estimated global population of insects, in quintillions, at any given moment

SOURCE: SMITHSONIAN INSTITUTE



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### Anti-Terror Honeybees

U.K. research group Inscintinel Ltd. trained honeybees to detect explosives. The team taught them to associate the scent of explosives residue with a sugary solution. When the bees sensed the residue, they repeatedly stuck out their tongues—an action picked up by computers.

### Mind-Controlled Beetles

In order to control green June beetles, University of Michigan researchers implanted electrodes in the beetles' nervous system and attached stimulators to their antennae. The intended purpose: search-and-rescue operations, surveillance, environmental monitoring, and explosives detection.

### Robotic Moths

University of Arizona researchers tested out a theory that they could interface living insect brains with robots. Using electrodes, researchers tapped into the neurons in a moth's visual system. When a moth saw an object, the brain activity would trigger the robot to turn and face it.

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